

NASA PARTNERSHIP WITH INDUSTRY:
ENHANCING TECHNOLOGY TRANSFER

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I, II

FOREWORD

Recognizing the need to accelerate and expand the application of NASA-derived technology for other civil uses in the United States, NASA officials asked the Denver Research Institute to examine how NASA might accomplish this goal through cooperative efforts with industry. The task statement was "to identify and assess the potential opportunities for NASA to expand the benefits of its technological capabilities through innovative cooperation with industry, to the mutual benefit of NASA, American industry, and the nation as a whole."

It is not as though NASA lacks experience in this process. For 20 years NASA has been a leader, through its Technology Utilization Program, in facilitating commercialization of technology originally developed for the agency's aerospace programs. More recently, activities have been introduced to exploit unique NASA capabilities related to the Space Shuttle, including joint endeavor agreements, technical exchange agreements, and guest investigator agreements--all directed toward cooperation with industry.

The purpose of this study has been to: (1) identify further opportunities; (2) explore the range of benefits to NASA, industry, and the nation; (3) assess public policy implications; and (4) relate this new range of opportunities to current technology transfer programs of NASA. The emphasis has been upon how NASA may improve its linkages with non-aerospace industries.

The study has built upon NASA's technology transfer experience as well as that of the Denver Research Institute in identifying and assessing new patterns of using NASA high technology capabilities in commercial applications.

The study was greatly aided by an Advisory Committee of eight persons of distinguished reputation in science and industry who have had a professional concern with the application of technology to social, economic and political goals. The committee made an invaluable contribution to the study through the members' insight and experience, by review of working papers, discussion at three separate meetings of issues related to the study, and by review of the report. The study owes much to the wisdom and dedication of the Advisory Committee members.

During the course of the study, DRI staff interviewed nearly 100 officials of NASA and industrial firms who provided valuable perspective and experience regarding means for technology transfer, opportunities and barriers to innovation, and the benefits and costs associated with such efforts. Finally, the study was helped immeasurably by the advice and assistance of Charles Mathews, retired, for 35 years a prominent NASA engineer/executive. The study team is indebted to the many officials in NASA and private industry who contributed to this effort.

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TABLE OF CONTENTS

	<u>Page</u>
Letter of Transmittal, Richard L. Chapman to James Beggs. . . .	i
Foreword.	iv
List of Advisory Committee Members.	v
 I. FINDINGS AND RECOMMENDATIONS FOR ACTION	 vii
Summary Biographies of Advisory Committee Members	xxi
Letter from James LaFleur to Richard L. Chapman	xxiv
Letter from Richard L. Chapman to James LaFleur	xxvi
 II. APPENDICES	
A. Technological Innovation and Economic Vitality.	A-1
B. The Development of NASA's Technology Transfer Program . . .	B-1
C. Factors Enhancing the Competitive Posture of Foreign Technology.	C-1
D. Industry Perspectives on Technology Transfer.	D-1
E. Selected Governmental Policies Affecting Technical Innovation in the American Economy.	E-1
F. Lessons From the Technology Transfer Experiences of Other Federal Departments and Agencies.	F-1
G. NASA Field Center Perspectives.	G-1
H. Evaluating Recommendations for Enhancing NASA's Technology Transfer Policy.	H-1
I. Case Studies of NASA-Industry Cooperation in the Transfer of Technology.	I-1
J. Illustrations of Industry-University Consortia.	J-1
K. The Future Environment for Technology Transfer.	K-1
 III. BIBLIOGRAPHY.	

PART I

FINDINGS AND RECOMMENDATIONS FOR ACTION

FINDINGS AND
RECOMMENDATIONS FOR ACTION BY NASA

"Many of the technologies of the 1960s and early 1970s were based on prewar science. . . . There is a big backlog of postwar science now maturing. We're seeing just the leading edge of its commercialization."¹

"Technology transfer is a hands-on process and not a mail room or brochure-type activity."²

These statements reflect two points that the Advisory Committee and the study team wish to emphasize: first, the time and circumstances are ripe for action by NASA; second, NASA action should focus upon one-to-one cooperation between its scientists and engineers and those in industry.

The following pages summarize the results of research into NASA's partnership with industry for transferring technology domestically. The discussion focuses upon the study's point of departure, findings, and action recommendations to the Administrator for enhancing technology transfer.

From the outset the study team and the Advisory Committee have accepted two fundamental tenets as points of departure for pursuing the task:

- (1) systematic and deliberate programs of technology transfer promote and strengthen NASA's primary mission of assuring U.S. leadership in the development and application of aeronautical and space science and technology; and,
- (2) an expanded emphasis on technology transfer is worth pursuing for what the U.S. economy in general can realize in terms of technical benefits as well as for the potential benefits to NASA.

Clearly, the potential benefits from exploiting technology are large.³ These benefits can only be realized, however, if the results of research and development can be moved successfully from the laboratory to the economy. As a primary supporter of R&D activities and generator of new technology, it is essential that the federal government pursue technology transfer activities.

¹William F. Miller, President, SRI International, quoted in Business Week, April 18, 1983, p. 79.

²William D. Carey, Executive Officer, American Association for the Advancement of Science, in letter to study director, November 2, 1982.

³See Appendix A, Technology Innovation and Economic Vitality, especially pp. 2-6, 11-17.

With or without the government's efforts, technology diffusion will occur through traditional lines of communication, publication, job turnover and so on. The Technology Utilization Program is NASA's formal effort to supplement this diffusion. By better understanding and capitalizing on these traditional processes, NASA's technology transfer efforts can stimulate the diffusion process to accomplishments beyond those of the Technology Utilization Program. The avenue explored here to expand technology transfer is through enhanced government-industry cooperation.

Why should NASA take the initiative among federal agencies in providing leadership on new ways to stimulate government-industry cooperation for the transfer and application of technology? First, NASA had a broader, more extensive technological base (including seven major laboratories and two flight stations) than any other agency except the Department of Defense. Second, NASA has an explicit legislative charter to pursue technology transfer. Third, NASA has the most experience with organized, successful programs for technology transfer. This combination of institutional leadership and program experience, spanning more than 20 years, places NASA in a unique position to take the initiative in exploring innovative ways to cooperate with American industry for the more effective exploitation of technology.⁴

Notwithstanding the opportunities at hand, and NASA's capability to make substantial progress, the Office of Management and Budget consistently has reduced substantially NASA requests to expand its technology transfer activities. It therefore behooves NASA to strengthen its efforts to document and demonstrate the value to NASA and to the general economy of technology transfer activities.

I. Findings

In pursuing this exploration, the study team developed eight working papers; the Advisory Committee met on two occasions; and members of the study team conducted over three dozen interviews with senior industry officials regarding innovation and technology transfer. In addition, the study director made visits to assess perceptions by the Center Directors and other officials at the seven NASA Field Centers. As a result, the Advisory Committee and study team reached these findings:

- Foreign high technology competition is real and must be met with positive approaches, e.g., the exploitation of U.S. technology domestically;
- Of seven public policy areas affecting technology transfer (tax, patent, antitrust, regulatory, conflict of interest, freedom of

⁴See Appendix B, The Development of NASA's Technology Transfer Program, pp. 1-6.

information, and R&D support), only three merit substantial NASA attention--patent, antitrust, and conflict of interest; and

- The conditions or factors for enhanced technology transfer can be identified and provide NASA with significant opportunities for action.

A. Foreign high technology competition. The traditional adversarial relationship between U.S. government agencies and the private sector must be ameliorated if the U.S. is to effectively meet foreign competition.⁵ The challenge cannot be met by the erection of barriers to impede the normal flow of technical information across national boundaries, nor by trade restrictions. Rather, we need to learn (within the context of our own socioeconomic system) from foreign examples, remove barriers to domestic technological applications within the United States consistent with military security, and encourage new ways to cooperate in mutual undertakings by government agencies and private companies. Cooperation between U.S. industry and government has historic precedents. More than a century ago such cooperation fostered the successful development of the railroads and modern agriculture. More recently, industry-government cooperation contributed to the nation's premier position in aeronautics.

B. The impact of public policy questions on technology transfer. The most important factor in the short run affecting the application of technology in the civil sector is the general state of the economy. As the economy slowed down over the past several years, the growth of research and development expenditures slowed, venture capital was restricted, and private firms generally shortened their perspectives with respect to investment, capitalization, and risk-taking in general. To paraphrase one investment specialist, the action that will have the largest impact on industry's willingness to invest in the application of technology is the reduction of interest rates to under 10 percent and an upswing in the general economy. Perhaps just as important, however, is the need for industry to be aware of potentially applicable new technology at a level of detail where value versus risk can be well understood. Whereas in the past applicable technology innovations usually occurred within a company, now they frequently occur outside, and cooperative efforts are required to assure timely awareness.⁶ NASA can improve its understanding of industry's needs and its ability to address those needs by monitoring the economy and taking note of how interest rates, foreign competition, and labor issues are affecting the industries with which it deals.

Seven general public policy areas were reviewed to assess their relative effect on technological innovation and transfer: tax policy, patent policy, antitrust policy, regulatory policy, research and development support policy, organizational conflict of interest policy,

⁵ See Appendix C, Factors Enhancing the Competitive Posture of Foreign High Technology, particularly pp. 27-31.

⁶ See Appendix D, Industry Perspectives on Technology Transfer, pp. 2-7.

and freedom of information policy. Although each of these areas has the potential to inhibit or facilitate the application of technology, current policies in these seven areas generally do not seriously impede increased NASA cooperation with industry or the transfer of technology.⁷

However, with regard to NASA policy, three areas deserve continued evaluation: patent policy, antitrust policy, and organizational conflict of interest. NASA policy basically has favored the private retention of patent rights, and a continuation of this stance will facilitate technology transfer. Although antitrust policy has not been much of a consideration in past NASA endeavors, increasing joint endeavors and similar cooperative activities will require some care.⁸ Recently the Justice Department, with the encouragement of the Department of Commerce, appears to be allowing greater flexibility for such arrangements (for example, the Justice Department's approval of the Microelectronic and Computer Technology Corporation--MCC). On the question of organizational conflict of interest, government interaction with private firms that confers benefits on those firms always raises questions about possible conflict of interest.⁹ The private sector is concerned that no special benefits are provided at public expense which give any one firm a competitive advantage over other firms. NASA should be sensitive to the issue and address it before it becomes a problem rather than later.

C. Conditions for the successful transfer of technology. Discussions with industry executives, reviews of past experience with NASA and other technology transfer programs, and discussions with officials at NASA Field Centers suggest that there are six conditions which, if met, can substantially facilitate, improve, and expand technology transfer:¹⁰

- a clear NASA policy regarding the concept and role of technology transfer--beyond that of the existing Technology Utilization Program;
- senior management commitment, supervision, and application of resources;
- improved understanding between NASA and nonaerospace industry;
- a technology transfer program built upon NASA's technical strengths and capabilities;
- emphasis upon Field Center technical capabilities and participation; and
- a framework of objectives, strategies, incentives and means for assessing and rewarding progress.

⁷ See Appendix E, Selected Governmental Policies Affecting Technical Innovation in the American Economy, pp. 44-47.

⁸ Ibid., pp. 12-18.

⁹ Ibid., pp. 36-37.

¹⁰ For other agency experience see Appendix F, Lessons From the Technology Transfer Experiences of other Federal Departments and Agencies, pp. 1-4.

Each of these conditions is addressed below:

1. A clear policy is needed regarding the concept and role of NASA technology transfer. Discussions with both industry and NASA officials reveal that NASA's technology transfer activities are perceived to have limited scope and marginal or sporadic management support. Basically, the role of NASA technology transfer usually is conceived to be: (1) limited to the Technology Utilization Program, (2) concerned principally with transfer from NASA to industry and not as a two-way process, and (3) a function of only marginal importance to NASA.¹¹

The whole array of technology transfer resources (including people, facilities and technology) needs to be brought within the focus of the term, and NASA policy appropriately adjusted to reflect this fact. The substantial promise of technology transfer through expanded cooperation with industry cannot be fulfilled until such a broader concept is instituted by the Administrator and permeates NASA.

The contrast between the broader concept of technology transfer and the current Technology Utilization Program is striking. A comprehensive concept of technology transfer includes, as a minimum, the following seven activities:

- (1) "hand-off" of major NASA technology applications programs--following proof of concept--to "users," operators, or developers; examples are meteorological or communications satellites, and aeronautics;*
- (2) transfer of technology by a NASA contractor to other clients or nonaerospace firms including its nonaerospace divisions;
- (3) modification of NASA technology by other than NASA contractors to meet nonaerospace applications;
- (4) application through specifications and new or revised industry-wide standards;
- (5) stimulation of new or expanded markets outside the normal aerospace contractor channels or subsystems as the result of NASA procurement;
- (6) problem solving through professional-to-professional communications (face-to-face or via telecommunications), within a discipline or technical area, often transferred by referral within an informal network; and

¹¹ See Appendix G, NASA Field Center Perspectives (pp. 2 and 6), and Appendix D, Industry Perspectives on Technology Transfer.

*Because of some 70 years of combined NACA and NASA experience, during which the NACA research community and the aeronautics industry "grew up" together, the nature of this synergistic relationship is somewhat different in aeronautics than elsewhere. However, there is reason to believe that some of the benefits can be duplicated if concerted attempts are made to develop the informal networks.

- (7) transfer of techniques/information through movement of people geographically or between organizations.

The current Technology Utilization Program is aimed primarily, but in a limited way, at the second and third activities listed above, and only occasionally becomes involved in the first and the sixth. Its primary modus operandi has been making information available through publication of Tech Briefs and subsequently of technical support packages (upon request)--both based on the new technology reporting system. The dissemination centers (such as COSMIC and the Industrial Application Centers) provide further detailed assistance to outside inquiries. More active programs, including Applications Teams and Applications Projects, have been considerably reduced in recent years because of budget constraints. Our review of past federal experiences shows the need to emphasize interactive transfer mechanisms and the establishment of cooperative partnerships with private industry. The more traditional passive approaches to transfer (such as publication) provide an essential foundation for these activities. By themselves, however, these passive approaches cannot produce the exploitation of federal technology that is desired.¹²

2. An expanded program of technology transfer will succeed only with senior management commitment, supervision, and application of resources. The most common response in discussion with leaders from industry and the NASA Field Centers was a polite skepticism about how serious NASA management is regarding technology transfer. Historically, the Technology Utilization Program has suffered a series of ups and downs in terms of management support and resources. Both industry officials and NASA Field Center leadership appear receptive to a new initiative for improved technology transfer; however, the responsiveness will be proportional to the energy and attention given by the Administrator to the visible resources committed to such new endeavors, and to the effectiveness of the means to assure program compliance.¹³ In short, there will be a considerable shortfall between the accomplishment and the potential of any new program of technology transfer unless the Administrator of NASA puts his enthusiasm behind the new emphasis. Building new relationships will require persistence and follow-through.

3. NASA needs to become better known and accepted by nonaerospace industry, with an improved understanding of industry within NASA. Our interviews with representatives of industry demonstrated that substantial ignorance continues to exist about the breadth and depth of NASA's technology programs, even among high technology industries. Several NASA Center Directors emphasized the viewpoint that NASA's principal challenge in the transfer of technology is to get "the right people" in industry familiar with NASA's programs and its technological capabilities.¹⁴ There is also considerable skepticism within industry about the appreciation among NASA scientists and engineers for the nature of goals and technical or economic problems which are of paramount interest to industry. Specifically, a common viewpoint is that

¹² Appendix F, p. 3.

¹³ Appendix G, p. 2.

¹⁴ Ibid., pp. 3-4.

NASA-derived design and development tends to ignore such problems as production cost, ease of manufacture, and marketability.¹⁵ These responses suggest that what is most needed is more frequent interaction on an engineer-to-engineer basis between NASA and industry. This interaction should maximize industry initiative with NASA personnel serving as catalytic agents. The above perceptions can be altered favorably if maximum use is made of industry institutions or those institutions normally used by industry.

4. A technology transfer program built upon NASA's technical strengths and capabilities will be most effective. The NACA/NASA program in aeronautical research over the past 68 years is acknowledged to be one of the best examples of successful technology transfer from the laboratory to practical use. An important part of this process was the informal cooperation and network of relationships between NACA/NASA researchers, educators in universities, and engineers in the aviation industry.¹⁶ The mutual trust, communications, and sharing of information grew out of the demonstration of NACA/NASA technical strengths valued by both academia and industry. Similar examples, such as NASA's work in materials, noise technology, and systems integration, make clear that the most likely avenues of cooperation between NASA and industry will be made on the basis of special NASA technological capability, leaving the specific product adaptation to industry.

5. Emphasize Field Center technical capabilities and participation. NASA's technical capabilities are located primarily in its Field Centers. Each Center has its own special set of capabilities and characteristics--technologically, managerially, and in operational style. Therefore, NASA Headquarters should concentrate on exercising general policy guidance and visible leadership rather than detailed management supervision in the¹⁷ process of facilitating outside contacts between industry and Field Centers.

6. A framework of objectives, strategies and means for assessing and rewarding progress will be required. A more encompassing concept of what constitutes technology transfer in NASA necessarily will require a revised set of objectives and means for assessing progress in order to assure needed guidance and subsequent responsiveness to these new directions. This new emphasis on cooperation with industry can be expected to encounter no less opposition in the Executive Branch resource justification and allocation process than has been the experience with the Technology Utilization Program. Therefore, it is important from the very outset that NASA systematically lay out the objectives, resource requirements, and assessment indicators. Resource implications of the enhanced effort are not so much in the area of increased R&D funding as in greater allocation of in-house man hours. Vague sentiments that technology is good for the nation are not enough to achieve the desired results. A comprehensive technology transfer program should identify potential technology users, lay out action steps, identify economic factors involved, and define criteria for success or failure.

¹⁵ Appendix D.

¹⁶ Appendix G, pp. 3,4,7.

¹⁷ Ibid., pp. 5-7.

II. Recommendations for Action

The most important action is to reconstitute NASA policy to reflect the expanded concept of technology transfer, as described above. Technology transfer should be viewed as the application of technology, derived from and for NASA programs, to solve problems in settings, locations, or organizations other than those for which it was principally developed, or for actual use beyond proof of concept. To implement such a policy two groups of actions are needed--one of an organizational nature, the other to expand cooperation with industry. In the first, the Administrator should institute organizational adjustments including planning and implementation activities that reflect this new policy by establishing technology transfer as a truly vital activity of NASA and the nation.

In the second, the Administrator should expand the channels of cooperation with industry through a variety of actions designed to increase contacts between engineers and scientists in NASA and in industry, to provide the environment for greater interchange of information and cooperation, and to explore new means of cooperative efforts, exchange of information and personnel, and other joint activities.

A. Establish Technology Transfer as a Vital Activity of NASA. Five actions are suggested for consideration, each of which would contribute to establishing the necessary environment for future program activities that have the potential for significantly strengthening and expanding NASA technology transfer activities:

- Focus leadership for technology transfer activities in NASA;
- Establish a central focus, but delegate transfer activities to Field Centers;
- Allocate additional resources to technology transfer activities;
- Establish a technology transfer activity fund at each Field Center; and
- Establish a NASA-wide technology transfer recognition program.

Each action recommendation is described below.

1. Focus the leadership for technology transfer activities in NASA by creation of a new position at the Associate Administrator or Associate Deputy Administrator level.¹⁸ Such action would be both symbolic and substantive. It would send a signal throughout the agency of the Administrator's commitment to this function. It also would give organizational authority to the function, as well as focusing attention on it. Thus it

¹⁸ See Appendix H, Evaluating Recommendations for Enhancing NASA's Technology Transfer Policy, pp. 5-7.

would give technology transfer a relative position of strength in relationships with other agencies, with the Executive Office of the President, with the Congress, and in dealings with private industry. It would provide a natural point of liaison for senior corporate officials to explore cooperative activities with NASA.

Because of its pervasive nature, the technology transfer function requires access to and continuing support of the Administrator; however, the quality and character of the person assigned is no less important than the level and nature of the position. The person heading this function should be one who is familiar with American industry (not just aerospace industry), who can work easily and well with senior industry officials, who is a mature, persuasive public speaker, and who has a close rapport with the Directors of the NASA Field Centers.

Location at the Associate Deputy Administrator level may be the most feasible since technology transfer is a cross cutting staff function whereas Associate Administrator functions tend to be program-oriented in nature. Also, an Associate Deputy Administrator usually is located in the Administrator's immediate office, and such an arrangement is consistent with past practices. It also would avoid the necessity of adding marginal or unrelated functions in order to justify the position. Steps short of this action are unlikely to convey the significance of the function.

2. 19 Establish a central focus but delegate technology transfer activities. Basically, the resources and authority to undertake specific programs should be delegated to the Field Centers, guided by appropriate objectives established for each Field Center, individually, after joint consultation and agreement on objectives and general strategies with the respective Field Center Directors.²⁰ The Associate Deputy Administrator for technology transfer would provide agency-wide leadership, coordination, and evaluation, as well as serving as the principal point of contact for corporation executives interested in cooperation with NASA.

3. A greater allocation of resources (funding and manpower) should be made to technology transfer activities.²¹ The type of expanded, new, or exploratory activities suggested here probably requires an increase of resources allocated to technology transfer activities. Any such change in a time of highly restricted budgets and in the face of continued opposition by the Office of Management and Budget will be difficult to obtain. However, it is also clear that those most involved in making technology transfer successful--persons in industry and in the NASA Field Centers--will not be convinced that NASA management is serious about exploiting technology transfer opportunities unless there is significant, overt evidence of willingness to invest resources in the process. This position relates as much or more

¹⁹ Ibid., pp. 7-9.

²⁰ Appendix G, pp. 5-6.

²¹ Appendix H, pp. 9-10.

to the use of in-house manpower as it does to funding. In fact, participation and incentives to do so should involve all NASA scientific and engineering talent. Revenue generated from technology transfer activities should be available to support them.

4. Establish a technology transfer activity fund at each Field Center under the authority of the Center Director.²² The purpose of such a fund would be to encourage broader participation by providing resources for: (1) applications projects, (2) travel and related costs associated with industry liaison activities, and (3) limited problem solving activities with industry, universities, and state or local governments. Field Center Directors should be authorized to receive reimbursement into this fund from industrial organizations and others. The funds would be allocated to each Field Center on a basis to be established by the Administrator. Such a fund would provide the flexibility to exploit technology transfer opportunities, and also serve to provide recognition for excellence in technology transfer performance.²³

5. Establish a NASA-wide recognition program for extraordinary accomplishment in technology transfer activities.²⁴ Such a program should include participation not only from NASA facilities, but from industry, universities, and non-profit organizations as well. Consideration should be given to establishing awards in conjunction with nonaerospace professional or technical societies. It might be patterned after the IR-100 award program. Incentives might also include individual monetary awards. Beyond this type of recognition, the technology transfer function should be included as a key element in performance evaluation and assessment during the annual performance review.

B. Expand the Channels of Cooperation With Industry. Past experience, both in the United States and in foreign countries where high technology is being aggressively pursued, shows that active cooperation in communication between government agencies and private industry significantly improves the likelihood of successful transfer of technology--in either direction.²⁵ Therefore, it is important that NASA pursue every reasonable opportunity to increase these ties, to become better known within the nonaerospace industry, and for NASA scientists and engineers to become more familiar with industry. Seven actions are suggested as practical means to further open channels of cooperation:

- Base cooperation upon (a) areas of NASA technical strength, or (b) areas of special interest to NASA;
- Join with industry, universities and research laboratories in consortia for research and technology exchanges, particularly those already established and proven effective;

²² Ibid., pp. 11-12.

²³ Appendix G, pp. 3-4.

²⁴ Appendix H, pp. 12-14.

²⁵ Appendix C, pp. 9-12.

- Expand joint endeavor activity beyond the current Materials Processing in Space Program to include the stimulation of bilateral ad hoc activities undertaken through Field Center initiative, and in conjunction with technical or professional societies;
- Bring top technical people from industry into NASA's technology planning process--much like the NACA committee/subcommittee system, including periodic peer review to assure program quality;
- Pilot test the feasibility of hosting engineers representing industry who would search and assess NASA technology for applications in their respective industries;
- Explore means by which to use industry-related publications as channels to publicize NASA technology; and
- Review with the U.S. Air Force additional means to expand or to assure an industrial base of support to space efforts.

These channels of cooperation are more fully explored below.

1. Cooperation should be based upon (a) areas of NASA technological strength or (b) areas of special interest to NASA.²⁷ The experience under NACA's aeronautics program, examples of NASA's successful technology transfer with nonaerospace companies, as well as experience with other agencies, all lead to the conclusion that the transfer of technology is most often successful when closely related to the technical strength of the transferring organization or to the particular technical interests of both the giving and of the receiving organization. In order to enhance the environment for technology transfer, NASA should survey its technological strengths, Center by Center, as well as outline its special technological interests in the future.²⁸ This information can provide one basis for further communication with industry and others regarding points of focus in potential transfer activities.

2. Join with industry, universities, and research laboratories in consortia for research and technology exchange.²⁹ Joining in such cooperative efforts provides the opportunity for NASA to augment its own technical capabilities in areas of interest. Also, while participating in a network for technological interchange NASA would have the opportunity to develop a more practical view of industries' needs. This type of activity runs the gamut from information and technology exchange, such as that at the University of Illinois Fracture Control Program, to major technology developments such as the Center for Integrated Systems at the Stanford University.³⁰ NASA should

²⁶ See Appendix I, Case Studies of NASA-Industry Cooperation in the Transfer of Technology, for three illustrations.

²⁷ Appendix H, pp. 14-15.

²⁸ For examples of current areas of technical strength, see Appendix G, p. 7.

²⁹ Appendix H, pp. 15-16.

³⁰ See Appendix J.

employ a variety of such centers to assess the relative value of different types of participation, their effectiveness for providing technology needed or desired by NASA, the extent to which they provide contacts for the transfer of NASA technology, and the extent to which they lead to further useful informal contacts. This approach would appear to require only modest funding, and to be effective without raising a high NASA profile.

3. Expand joint endeavor activity beyond the current Materials Processing in Space Program.³¹ Thus far, NASA's joint endeavor activity in the current MPS Program has not been extensive. Nevertheless, as a first step towards exploring the feasibility of further expansion of this type of activity, NASA should determine which of its own programs appear promising for joint activity with private industry. Then, efforts should be made to engage appropriate industry partners. Use of NASA facilities by industry also should be considered.

4. Bring industry representatives into NASA's technology planning process.³² NACA's success in gearing its research to industry needs has been linked to the close participation by highly qualified representatives of the aeronautics industry in the NACA aeronautical research planning process.³³ NASA should explore the feasibility of carefully extending this process to other areas of technology. This process might also include periodic peer review to assure continuing quality. To some extent, a similar process has been achieved through National Academy of Science's advisory groups and committees, periodically reviewing NASA plans and opportunities. However, it is considerably more removed from industry than was that of the NACA committee and subcommittee system. As part of the process of exploring this feasibility, NASA will have to review the potential problem of conflict of interest.

5. Pilot test the feasibility of encouraging engineers, representing industry, to search and assess NASA technology for applications.³⁴ Here, guest engineers would be given extensive access to data systems and Field Center personnel for the purpose of identifying potential applications or solutions to problems of a particular industry. Salaries of such individuals would be paid by the company or group of industries represented. They would be selected by their respective participating company or industry association. NASA (at least in the pilot stage) would absorb the cost of making NASA engineers and scientists available for brief consultation with these persons and for some internal data search. Conflict of interest questions would have to be considered in implementing this activity.

6. Explore means to use industry-related publications as channels to publicize NASA technology.³⁵ Under the current program, NASA depends largely upon its NASA Tech Briefs as the means of announcing new developments in

³¹Appendix H, p. 17.

³²Ibid., pp. 17-19.

³³Appendix G, pp. 5-6 and Appendix D.

³⁴Appendix H, pp. 19-20.

³⁵Ibid., pp. 20-21.

NASA technology that are considered to be of interest to industry and of commercial potential. Although this provides for "broadcast" publication, discussions with industrial officials reveal that this means is unlikely to reach many decision makers in nonaerospace industry. NASA should reexamine possible opportunities for placing similar information about its technology in publications of professional and trade organizations and at trade fairs, meetings and informal information networks sponsored by such groups. Reportedly, this was explored during the early years of the Technology Utilization Program, but there was little receptivity by those responsible for the publications. Another review would be timely.

7. Review with the U.S. Air Force additional means to expand or assure an aerospace industrial base.³⁶ NASA is reported to be involved in a joint effort with the Air Force to improve manufacturing technology and to provide information about such improvements more broadly to the aerospace industry. This suggestion is directed toward expanding the industries from which future work might be solicited. This can be pursued through the wider sharing of information, a better understanding of the capabilities of those industries not currently doing business with NASA, and establishing a broader base of firms acquainted with aerospace technology. An assessment should be made of what steps NASA might take, via the contract route or other means, to engage in broader participation and ultimately further transfer of technology. Various high technology industries operating outside of aerospace seem a likely group to attract. Since the industrial base serving the Air Force is similar to that of NASA, a cooperative effort with the Air Force could make such an exploration considerably more fruitful.

Postscript

A recent editorial, appearing in an aerospace company's in-house magazine, pleaded the case for working at technology transfer by combating the false myths many hold regarding technology transfer.³⁷ The myths are: (1) that industry automatically "gobbles up" new technology as soon as it is revealed, (2) that a "better mousetrap" is self-evident and doesn't need selling, and (3) that "exciting and valid" technology will "automatically" be transferred. All of these myths are founded in the erroneous belief that worthwhile transfer is a self-servicing system. The basic point of the editorial, as of this report, is that a company or agency must be organized to enhance technology transfer if the right connections are to be made and technology most effectively applied--and this requires conscious effort throughout an organization.

³⁶ Ibid., p. 21.

³⁷ TRW Electronics & Defense/Quest, Winter, 1982-1983, p. 65.

xxi
PARTNERSHIP ADVISORY COMMITTEE
BIOGRAPHICAL SUMMARIES

James C. Armstrong: Since 1972 Dr. Armstrong has been with the American Telephone and Telegraph Company where he is currently Director, Strategic Planning. He served four years in the Office of the Postmaster General as Director of Support Planning, and as Director of the Systems Analysis Division. He also worked at the Institute for Defense Analysis and was Research Associate and Assistant Professor of Physics at the University of Maryland. Currently an Adjunct Professor of Management at Pace University in New York, he has served as a consultant to a number of scientific and technical organizations.

Lamont Eltinge: Dr. Eltinge joined Eaton Corporation in 1973, and as Director of Research, has focused upon the identification and assimilation of new technologies. He has experience in manufacturing at the Electro-Motive Division of General Motors, and industrial research--predominantly in engine, fuel, energy, and ecology fields. He served in the Research and Development Department of the Standard Oil Company of Indiana, directed automotive research for the Ethyl Corporation, and was Vice President of Research and Technology for the Cummins Engine Company.

William T. Golden: Mr. Golden is director and trustee of several national corporations; Director and Treasurer of the American Association for the Advancement of Science; trustee of Mitre Corporation, Carnegie Institution of Washington, Center for Advanced Study in the Behavioral Sciences, American Museum of Natural History, and others. He has been a Member of the Department of State Advisory Commission on Private Enterprise in Foreign Aid, a Member of the Military Procurement Task Force of the Second Hoover Commission, Special Consultant to President Truman on government organization for science, consultant to the Director of the Bureau of the Budget, and Assistant to the Commissioner, Atomic Energy Commission.

Augustus B. Kinzel: Dr. Kinzel is director and trustee of several national corporations; serves as trustee of the Systems Development Foundation, the California Institute of Technology, and the Brookhaven National Laboratory. He has served on the Defense Science Board, the Naval Research Advisory Committee and others, and was Chief Consultant in Metallurgy to the Manhattan District and its successors. From 1926 when he joined Union Carbide and Carbon Research Laboratories, Inc., he served in research and management positions, rising to Director of Research, then Vice President for Research of Union Carbide Corporation. Subsequently, he was President and Chief Executive Officer of the Salk Institute of Biological Studies. He is a member of the National Academy of Sciences and was Founding President of the National Academy of Engineering.

James K. LaFleur: Mr. LaFleur has been President, Chief Executive Officer and Chairman of the Board of Directors of GTI Corporation since 1975. He was founder and president of three high technology companies, and has engaged in a private technological consulting practice. He is a registered professional engineer and has been awarded over 130 patents in the U.S. and foreign countries in the fields of turbomachinery and cryogenics. He authored the recent monograph, "R&D Limited Partnership: A Financial Breakthrough for Inventors and Small Businesses."

Gordon H. Millar: Dr. Millar has been associated with Deere and Company since 1963 at which time he was Director of Research for six years, followed by several years as Assistant General Manager of the Tractor Works (Waterloo), and since 1972 has been Vice President for Engineering. Previously he served as Engineering Manager for Meriam Instrument Company and as Director for New Products of McCulloch Corporation. He is a member of the National Academy of Engineering.

Jerome Simonoff: Mr. Simonoff, currently Vice President, has been associated with Citicorp Industrial Credit, Inc., since 1967, with principal involvement in financing high growth computer and telecommunications companies. Prior to joining Citicorp, he worked at the Johns Hopkins Applied Physics Laboratories, engaged in economic studies and test plans for the application of satellite technology to assist navigation of submarines. He worked on the electronic design of data communications equipment and flight simulator computers at ACF Industries, Inc., from 1961-63.

John G. Welles: Mr. Welles has been Vice President for Planning and Public Affairs, Colorado School of Mines, since 1974. For 18 years previously he was Head, Industrial Economics Division, University of Denver Research Institute specializing in research on the management of R&D, technology transfer, and regional development. He has worked in engineering with the General Electric Company, labor relations with General Motors, and as a consultant to the U.N. Conference on the Human Environment and to Business International. In 1975 and 1980 he served as chairman of the Colorado Front-Range Project on part-time loan to the Governor's office.



James K. La Fleur
President

May 5, 1983

Mr. Richard Chapman
Project Director
Program for Transfer Research
and Impact Studies
University of Denver
University Park
Denver, Colorado 80208

Dear Dick:

I would like to offer the following comments relative to the final recommendations that are made to NASA regarding the Technology Transfer Project.

1. I concur that technology transfer is desirable from the point of view of advancing this country's scientific efforts. However efforts to facilitate this transfer in an open society will always run directly counter to the desire to prevent or slow down the transfer of the identical technology to unfriendly world powers. A judgemental call must then be made between these opposing and somewhat mutually exclusive goals.

2. NASA has always maintained a policy of sub-contracting the major portion of its hardware fabrication requirements to the private sector. The major sub-contractors to NASA have in turn sub-contracted large portions of their work to smaller firms. This policy has not only worked to the mutual benefit of the government and industry in the general sense of procuring high quality hardware but has had a secondary and generally unnoticed benefit of transferring technology from NASA to industry in accordance with Congressional desires. In fact, it could be argued, that lacking the one-to-one relationship that existed between N.A.C.A. and the aircraft industry, that the sub-contracting policy pursued by NASA since its inception was the most effective way of transferring multi-disciplined space technology into the private sector.

Mr. Richard Chapman
Page 2
May 5, 1983

3. There is pressure everywhere to reduce government expenses. Recommending increased spending to accomplish something that may already be occurring seems contrary to national policy and good judgement at this time.

In view of the above, my recommendations would be:

1. Eliminate technology transfer as a separate and overt activity.
2. Develop arguments that the Congressional mandate for technology transfer is already being implemented at no cost via NASA's subcontracting policy. I believe statistics are available to indicate that a significant percentage of American industry has benefited from technology acquired in this fashion.

Dick, regardless of the outcome, I would not allow my name to appear on a report that recommended a budget increase for this activity.

Several other recommendations in the report are defective in that implementation is either impossible or extremely difficult. I will elaborate if you feel it is necessary, but if my suggestions above were accepted, nothing more need be said.

Incidentally, why not recommend a program be dropped? You might gain more respect by giving a straight forward, simple recommendation. It is not always necessary to conclude a study with a recommendation that the program under study be expanded.

Sincerely,

A handwritten signature, likely of the sender, is written in dark ink. It is a cursive-style signature that is somewhat stylized and difficult to read precisely, but appears to start with a capital letter.

JKL:nt

COPY



COPY

UNIVERSITY OF DENVER

An Independent University

University Park, Denver, Colorado 80208

Denver Research Institute

Industrial Economics Division

May 20, 1983

Mr. James R. LaFleur, President
GTI Corporation
10060 Willow Creek Road
San Diego, CA 92131

Dear Jim:

[paragraph of personal reference deleted]

Let me address the main points of your May 5th letter regarding final recommendations to NASA on technology transfer.

First, your observation regarding the conflict between facilitating transfer in an open society and restricting transfer to unfriendly nations is, I believe, shared among the other members of the committee. The judgment call has to be made in terms of the full benefits and costs to the Nation for any set of general policies or particular action.

Second, your point about the NASA procurement process as a natural and effective channel for transfer is recognized. However, nearly two decades of experience reveal that procurement is but one of a number of effective channels for transfer, and that other channels can be opened or encouraged with but minimum (albeit organized) effort. The Deere and Company activity, to take one example, simply would not have occurred had it depended upon NASA procurement activity as the mode for transfer.

Third, I believe most of us on this project agree that budget constraints dictate a strategy of caution regarding new spending; but that does not preclude readjustment or reallocation of resources within NASA.

Finally, the discussions in the committee meetings, and the background materials developed from research, field visits, and interviews--all point toward the desirability (and utility) of an enhanced, if redirected, NASA technology transfer effort. This is substantially at variance with your suggestion that technology transfer as a separate and overt activity be dropped. [Personal reference deleted.]

May 20, 1983

Since you disagree with the basic sense of the draft report, let me suggest that we note that in the memorandum to Beggs, appending any comments that you wish to make, or include a copy of your May 5th letter. The transmittal letter will be amended to reflect consensus among seven of the eight members of the Advisory Committee. [Administrative reference deleted.]

Sincerely,



Richard L. Chapman

RLC:jb

cc: Advisory Committee members

Note: The other members of the Advisory Committee agree with the argumentation outlined above. In addition several points were made by members in their response: (1) if NASA were to eliminate overt, organized efforts at technology transfer, relying only on their regular contracting practices (in contrast to those recommended), there would be little or no transfer to non-aerospace industry; (2) ideally, technology transfer should not be a separate activity, distinct from line management, but should be integrated into line management responsibility; and (3) although clearly not the primary activity of NASA, technology transfer needs to be an overt, recognized NASA activity of legitimate concern to line management.

PART II

APPENDICES

APPENDIX A

Technological Innovation and Economic Vitality

J. Gordon Milliken

NASA Partnership Study
Industrial Economics and Management Division
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TECHNOLOGICAL INNOVATION AND ECONOMIC VITALITY

Over the last two decades, certain economists have studied and researched the relationships among U.S. public and private investment in R&D, the pace of technological innovation, and the resulting impacts on the economic vitality of the nation. One of the most prominent of these economists has described the significance of these impacts on national well-being:

There has been a growing conviction in government and elsewhere that the American economy is not growing as rapidly as it should, and a growing awareness that our rate of economic growth depends very heavily on our rate of technical change. Second, the advent and continuation of the cold war has made it painfully obvious that our national security depends on the output of our military research and development effort. Third, economists and others are coming to realize the full importance in various markets of competition through new products and processes rather than direct price competition. Fourth, unemployment created or aggravated by technical change has become increasingly acute, the problem reaching such dimensions that the President recently labeled it one of the foremost problems of the sixties.¹

This observation, made 18 years ago, remains timely in 1983.

There is substantial evidence that the economic problems of the U.S.--competitiveness of our industries in world trade, inflation, productivity, and unemployment--are related to the innovation process. These relationships will be discussed later.

Further evidence exists that the process of technological innovation is not solely the responsibility of the public sector, nor solely of the private sector. Frank Press, then Director of the Office of Science and Technology Policy, implied that joint public-private efforts are needed:

The relationship between government and industry in promoting the productivity and competitiveness of U.S. industry is now a very important item on this nation's agenda. It is evident today that the health of our economy is being adversely affected by a lag in our productivity and a decline in our industrial innovation. A reversal of this situation is essential, not only for the domestic effect, but also to improve our competitive position in world markets. . . . We are already aware of certain conditions that need correction:

- There is insufficient incentive on the part of industry to innovate boldly--industry leaders tell us that it is "safer" to market incremental improvements in tried and true products than to undertake greatly innovative R&D.
- Industry investment is too low on exploratory research, particularly that from which the results would be more advantageous to society as a whole rather than one firm or industry in particular.
- Industrial research managers tell us that they are having to put a larger share of their income into so-called "defensive" measures to meet new environmental and consumer safety standards--as desirable as these standards may be. . . . We must recognize that they require resources that might otherwise be used for more innovative work.
- Equipment and facilities are aging and not being replaced as rapidly as necessary to keep U.S. industries productive and competitive.²

Technological Change and the Economy

Technological change is generally defined as an innovation that results in a change in the production function. That is to say, it involves the introduction of an improved method, or material, or item of equipment in such a way as to increase the maximum output of a product (or service) that can be obtained from a given amount of inputs (factors of production such as labor and capital). A technological change also may result in

the availability of new products. An innovation may, but often does not, stem from an invention nor from a fundamental advance in scientific knowledge or principles. Many innovations occur by transfer and/or adaptation of known technology from one economic sector, or industry, or nation, to another. A first use in a particular setting can be called an innovation.

The rate of technological change is generally measured indirectly, by measuring its effects on productivity. There are several such measures, including the common one of change in output per manhour of labor. Other measures involve capital inputs as well. All, however, suffer from the limitations inherent in separating technological change effects from effects caused by extraneous factors. Nevertheless, economists have developed a total productivity index which reflects a rate of productivity growth of about 1.7 percent per year during the 1889-1957 period, rising faster in periods of economic expansion than in contraction/recessions.³

The rate of technological change, most economists agree, is determined by the aggregate investment by industry, government, and individual inventors in the improvement of technology. Some dozen econometric studies have been carried out by teams of economists in recent years, using regression techniques to relate changes in output over time with changes in the R&D expenditure, labor and capital invested by firms in a particular industry. Mansfield summarizes their economic findings:

These econometric studies provide persuasive evidence that R&D has a significant effect on the rate of productivity increase in the industries and time periods that have been studied. Indeed, every study comes to essentially this same conclusion. (To illustrate the similarity of the results, three

entirely independent studies . . . used quite different data to estimate the elasticity of output with respect to cumulated R and D expenditures in the chemical industry, and all three found it was about .1.) However, there is, of course, a lag between the time when the R and D expenditures occur, and the time of the productivity increase. This lag tends to be longer for more basic research than for applied research, and longer for applied research than for development. For major innovations, the lag between invention and commercialization may be a decade or more, but for more run-of-the-mill projects, the lag often is much shorter.⁴

He goes on to point out several limitations to these econometric studies, such as inadequate reflection of changes in the quality of goods and services produced, problems in measuring inputs--notably capital investment, changes over time in the comparability of data on R&D expenditure, extraneous factors affecting correlation--such as the likelihood that firms investing large amounts in R&D may also have progressive management that independently advances productivity.

Possibly the most significant of these is the failure to give proper credit and weight to improvements in the quality of goods and services produced. Quality improvements are an important result of R&D. Mansfield notes that the nation's economic "growth rate would have been the same whether antibiotics were developed or not, or whether we devoted the resources used to reach the moon to public works. . . . Unfortunately, the measured growth of national income fails to register or indicate the effects on consumer welfare of the increased spectrum of choice arising from the introduction of new products."⁵

Christopher Freeman discusses several other problems with measures of R&D input as a surrogate for output, including the anomaly that similar

research expenditures may or may not appear in GNP statistics. They do appear if government financed, whether performed by government or industry. They do not if the R&D is financed and carried out within the industrial firm, as it will not be measured as a final product.⁶

Several alternate measures of R&D output are proposed and discussed by Freeman, such as patent statistics and numbers of scientific papers published, but each has deficiencies. So does the difficult and lengthy task of cost-benefit analysis of innovations, which in any case cannot properly measure the indirect benefits resulting from the extraneous flow of new technological information stemming from the innovation process but flowing in many directions and used with varying time-lags.⁷

Social Returns on R&D Investments

In the last several years, economists have devised techniques for providing at least rough estimates of the social rates of return from technological innovations. Analogous to the rate of return earned on a private investment, the social rate of return represents the interest rate received by society as a whole from the investment in a new technology. In 1977, published estimates were reported of the social rates of return for 17 technological innovations. The median social rate of return from these was a striking 56 percent annually, "which indicates that the investments in these technologies paid off handsomely from society's point of view."^{8,9} This is compelling evidence that broad societal benefits can flow from R&D investments. That finding bears further consideration when considering national policy on technological innovations.

Public vs. Private Rates of Return on R&D Investments

Intuitively, the rate of return to a firm that invests in R&D would be less than the rate of return to society as a whole, since there are likely to be external benefits from flows of technology to others. Some evidence of this was presented in the 17 case studies mentioned above. In these, the median private rate of return (before taxes) was about 25 percent, which rate corresponds to the marginal rates of return of 30-40 percent calculated by Mansfield in the chemical and petroleum industries. In one case of an industrial product innovation, the social rate of return was over 300 percent while the private rate of return was only 27 percent, partly because of imitation by competitive firms within six months of its introduction by the innovator.¹⁰

But will the investment in R&D take place so society can benefit in cases where the perceived private rate of return is too low to provide an incentive to the potential innovator? No, it will not, so long as the firm or innovator acts rationally in economic terms. (Other research on selection of R&D projects indicates that while risk of technical success and risk of commercial success are weighed before the decision to proceed, so are other less economically rational factors such as the challenge to the interest of the research staff.) Of the 17 innovations in Mansfield's case study, in nine cases data were available on the expected rate of return to the innovator before the project was begun. In five of the nine, the private rate of return was less than 15 percent (before taxes) or quite marginal indeed. Yet the average social rate of return of these five innovations was more than 100 percent. In about 30 percent of the 17 cases in the sample, the private rate of return was so low that no firm, with the

benefit of hindsight, would have invested in the innovation. Yet the social rate of return was high enough to show the worthwhile nature of the investment from society's point of view.¹¹

This evidence seems to point to the likelihood of a substantial underinvestment in civilian technology because the R&D investment decision is made by the innovating firm. Where the private rate of return is too low to encourage investment, the [usually] greater social rate of return must be foregone by society. Some public policy implications of this circumstance will be discussed later.

R&D Expenditure Trends in the U.S.

Detailed studies of R&D investments in the chemical, petroleum and steel industries determined that there is a close relationship over the long run between the amount a firm spends on R&D and the total number of important inventions it produces.¹² Not a surprising finding, but one comforting to research professionals and research managers.

Although the relationship between R&D expenditures and technological advance cannot automatically be extended to nations, it is nonetheless unsettling to view statistics on the trend of aggregate R&D investment in the United States:

From the end of World War II until the late 1960s, the nation's expenditures on research and development increased at a relatively rapid rate. [From \$1.5 billion in 1945 to \$17.4 billion in 1963.] But from 1968 to 1975, when inflation is taken roughly into account, evidence presented by the National Science Foundation seems to indicate a decline in the total expenditures on R&D in constant dollars. The number of scientists and engineers engaged in R&D also declined--from 560,000 in 1969 to 520,000 in 1973. Some policy makers and economists have been concerned that

this decline may have a detrimental effect on the nation's future rate of economic growth.^{13,14}

Adding additional concern is the concentration of R&D expenditures in certain technological fields. During the early 1960's, over 55 percent of the nation's R&D expenditures were for defense and space technology purposes. This had declined subsequently, to 43 percent in 1970.¹⁵ However, three federal agencies--the Department of Defense, NASA, and the Atomic Energy Commission--accounted for 90 percent of the R&D expenditures of the federal government in the late 1960's.¹⁶ Furthermore, much of the R&D performed by U.S. industry is financed by the federal government. In 1974, about 40 percent of the industrial R&D was federally funded. Much of this R&D also is defense and space oriented, although in recent years there has been some shift in emphasis toward energy and environmental research.¹⁷

R&D financed and conducted by the U.S. private industrial sector--which totalled \$14 billion in 1974--was highly concentrated in five industries. Four-fifths of the R&D performed by U.S. industry was concentrated in five industrial classifications: electrical equipment and communications, chemicals and allied products, machinery, motor vehicles, and aircraft and missiles.¹⁸ This phenomenon may in part be a function of size of firm. Several economists have stated that in recent years innovations have been carried out primarily by large firms* because: (a) the costs of innovating

*A contrary opinion is expressed by Christopher Layton, who notes that

The best conditions for innovation are nonetheless often found in small companies, where communications between development, productions and marketing are easy and a common objective, with strategies to implement it, can be understood by all concerned. Statistically there is evidence that a very high proportion of original inventions have come from individual inventors, without

are too great for smaller firms; (b) R&D projects must be carried out on a large enough scale to spread risk, so that there will be a probability of successes balancing out failures; and (c) a firm must have sufficient control over the market to reap the rewards of an innovation, to make it worthwhile to assume the costs.²⁰

Types of R&D Expenditures in the U.S.

Compounding the declining trend in U.S. research and development expenditures is an evident shift in industry-sponsored research away from the risky and ambitious projects, including basic research and long term projects with expectations of significant time lapse before payout. If there is indeed a shift of this type to the less risky projects involving incremental product and process improvements, it presents an ominous outlook for our future as innovators. Scientific breakthroughs are unlikely to result from low risk R&D involving incremental product improvements. The aphorism, "No guts--no glory"* may apply in R&D as well as other enterprises.

Mansfield has categorized industrial R&D expenditures as being mainly (about two thirds) for development, with particularly large proportions going for development in the machinery, electrical equipment and aircraft and missiles industries. Over all industries, about one third of

the initial backing of any organization. There is a good deal of dispute about whether large or small firms are then a better environment for the development, production and marketing of a new product or process (innovation); it often depends on the scale of the R and D investment needed. Our study suggested, however, that it was easier to get a successful innovation effort going in small or relatively small enterprises.¹⁹

*The original is more elegant: "Quien no se atreve no pasa la mar"; He who does not dare does not cross the sea.

expenditures are for research and only one eighth go for basic research. He cites a 1975 survey showing that half of the responding firms' R&D expenditures were aimed at improving existing products, while 36 percent were aimed at new product development and 14 percent at new process development.²¹

Subsequently, Mansfield studied 119 firms to explore the hypothesis that the proportion of industrial R&D expenditures on risky and ambitious projects is declining. He confirmed the hypothesis:

The proportion of R&D expenditures devoted to basic research declined between 1967 and 1977 in practically every industry. In the aerospace, metals, electrical equipment, office equipment and computer, chemical, drug, and rubber industries, this proportion dropped substantially. In the sample as a whole, the proportion fell about one-fourth from 5.6 percent in 1967 to 4.1 percent in 1977. . . .* In four-fifths of the industries, there was also a decline between 1967 and 1977 in the proportion of R&D expenditures devoted to relatively risky projects (specifically, ones with less than a fifty-fifty estimated chance of success). In some industries, like metals, chemicals, aircraft, drugs, and rubber, this reduction has been rather large.²²

Mansfield also sought reasons for the reduction from those firms that have reduced the proportion of R&D spending on basic research and relatively risky and long term projects. The most frequently cited reason was the increase in government regulations that has reduced potential profitability of projects; chemical and drug firms were the likeliest to cite this. Another reason given was that because of the extensive amount of R&D already done, breakthroughs are more difficult to achieve than

*By comparison, Freeman surveyed 221 British firms in 1959-60 and found that 6.5 percent of R&D expenditures were for basic research.

in the past.* A third reason was high rates of inflation. This certainly could contribute to a reduction, as much higher rates of return would be needed to justify longer term payouts and higher risk projects. Mansfield concludes that the reduction in the proportion of R&D expenditures for basic research, relatively risky and longer term projects may put a damper on the rate of productivity increase.²³

Inflation and the high cost of capital are seen as more severely impacting innovative, technology-intensive firms than more traditional industries:

The needs of fast-growing, knowledge-intensive, high technology companies are significantly different from those of slower growing, capital-intensive industries. Slower growing companies generate most of their capital from internally generated profits By contrast, fast-growing high technology firms that are not so capital intensive look to the equity market for start-up and expansion capital. Moreover, their future growth is dependent on high risk investments in research and development (R&D). . . .

[Thus] the present high cost of capital discourages high risk investments in new technology.²⁴

Technological Innovation, Productivity and Inflation

Over the past 25 years, research by the National Bureau of Economic Research, Mansfield and others has attempted to define the relationship between R&D expenditures and productivity increase in particular industries. A 1959 thesis by N. Terleckyj found that the rate of growth of total factor productivity increased by about 0.5 percent for each tenfold increase in

*One is reminded of the 19th century head of the U.S. Patent Office who supposedly resigned because everything that could be had been invented already.

the ratio of R&D expenditure to sales. Subsequent work by Mansfield in the mid-1960s found that both for firms and for industries, the measured rate of productivity change was related in a statistically significant way to the rate of growth of cumulated R&D expenditures made by the firm or industry. If the technological change is embodied in new equipment, a 0.7 percent increase in the rate of productivity increase results from every 1.0 percent increase in the rate of growth of cumulated R&D expenditures. If the technological change is disembodied, e.g., better methods or organization, there is a 0.1 percent increase in the rate of productivity increase for each 1.0 percent increase in the rate of growth of R&D spending. Mansfield concludes: ". . . although econometric studies of the relationship between R&D and productivity increase have . . . many limitations, they provide reasonably persuasive evidence that R&D has an important effect on productivity increase in the industries and time periods that have been studied."²⁵

More specifically, the works of Solow and Denison were cited. Solow found that between 1909 and 1949, the average rate of technological change was about 1.5 percent per year and that about 90 percent of the increase in output per capita during this period was due to technological change and only a minor proportion was due to increases in the amount of capital employed per worker. Denison found that "the advance of knowledge," or technological innovation, accounted for about 40 percent of the total increase in national income per person employed during 1929-57.²⁶

In 1976 testimony before the House of Representatives Committee on Science and Technology, Mansfield made a stronger connection between R&D expenditures and the economy, although he ranked technological innovation

behind the more obvious economic tools--monetary and fiscal policy--as solutions to problems of unemployment and inflation:

Nonetheless, our science and technology policies can have important long-run effects, assuming that proper fiscal and monetary policies are adopted. In particular, . . . there is a great deal of evidence that R and D expenditures are directly related to the rate of productivity growth (allowing for a time lag). Since increases in the rate of productivity growth can offset increases in labor, materials, and other costs, they can tend to moderate the inflation rate. Thus, our technological policies can have a noteworthy, if secondary, influence on inflation, as well as a major influence on our rate of economic growth.²⁷

Using examples from two industries, Mansfield explained how R&D tends to reduce inflation, at least in the medium and long run, through its effects on productivity. In petroleum refining, introduction of new cracking processes reduced the cost of gasoline in 1955 to about 18 percent of the cost using the earlier Burton process. The development of large-scale ammonia plants in the 1960's reduced the cost of ammonia by over 20 percent.^{28,29}

He also points out two other concerns stemming from the interaction among R&D expenditures, productivity and inflation. If inflation is high, as it was during most of the last decade, it distorts the efficiency of the price system as a mechanism for coordinating economic activity and the allocation of resources, with resulting disastrous effects on productivity. Further, high inflation rates deter investment and thus discourage R&D expenditures that require new plant and equipment for its utilization. Even when R&D expenditures remain steady or grow they fund projects which are not as ambitious and risk-taking as under price stability.³⁰

Thus forms a vicious cycle of low R&D expenditure deterring productivity, a low national productivity fueling inflation, inflation distorting the price system and leading to purchases and investments that are less rational and further destructive of productivity, and the resulting enhanced inflation further discouraging R&D expenditure.

Technological Innovation and Competitiveness in World Markets

During much of the century from 1850 on, the United States enjoyed a technological lead in many fields. It was the heyday of American invention and innovation, with such breakthroughs as interchangeable parts. The U.S. had a strong export position and could outperform much of the manufacturing competition from Europe, as well as other less developed nations, despite a superior wage paid to American workers. The technological gap which continued into the 1960s was the subject of considerable study by economists. Some showed that most of the U.S. exports were in new products which other countries were not yet producing--clear evidence of strong technological innovation in the U.S., but a strength that is impermanent and subject to attack by imitators. A series of studies by the OECD in the late 1960s found that a large gap existed in computers and some electronic components but not in pharmaceuticals, plastics, iron and steel, non-ferrous metals, machine tools and scientific instruments (except for certain specialized subsectors). Thus the American technological lead was greatest in relatively research-intensive sectors of the economy. Furthermore, the OECD found that another factor in the U.S. technological lead was the U.S. superior expertise in techniques of management, including the management of R&D and the coupling of R&D with marketing and production.*³¹

*For a useful comparison of U.S. and U.K. allocations of skilled manpower to marketing and production, see Layton, 1972, Chapter 2.

However superior the U.S. may have been in technological innovation through the mid-1960s, there is substantial evidence that the U.S. lead has eroded rapidly in the meantime and the downward trend in U.S. technological competitiveness continues. There are many indicators of decline:

- Decreasing private investment in the research that could lead to new products and processes.
- The increased emphasis in private sector R&D activity upon low risk, short-term projects aimed at incremental product changes.
- The declining international competitiveness of U.S. industry as reflected in trade deficits, the shrinking number of industrial product lines that account for U.S. exports, and the increasing penetration of domestic markets by foreign [producers] of intermediate technology and basic industrial goods.
- The fact that in some industries the level of technology used in production lags behind that in other countries (for example, coal mining and steel production).
- The difficulties in obtaining venture capital by small, high technology firms.
- The changed direction of industrial research resulting from the diversion of corporate expenditures from commercial to other goals.³²
- As a percentage of gross national product, R. & D. expenditure has decreased in the United States for the past 15 years, whereas it has increased in Japan, Germany, and the Soviet Union. Moreover, the United States devotes a much greater percentage of its R. & D. to defense and space than does Japan or Germany. Thus, the ratio of civilian R. & D. to gross national product is considerably higher in Japan and Germany than in the United States. In 1974, it was 2.27 percent in Germany, 1.91 percent in Japan, and 1.46 percent in the United States.³³

The results are all too clear. In many of the areas where the U.S. still maintains a favorable balance of trade--aircraft, chemicals, electrical equipment and instruments--the continuing U.S. advantage appears due to the

technological superiority based on an intensive investment in R&D. In contrast, in manufacturing industries which are not typified by heavy R&D investment, the U.S. has experienced a large and continuing negative trade balance over the decade of the 1970s. Mansfield comments:

Although it is very difficult to measure international differences in technological levels, the available evidence suggests that the United States long has been a leader in technology, but in the past 15 or 20 years, the U.S. technological lead has been reduced in many areas. In some areas, it no longer exists at all.

This seems to be the judgment of many leading engineers, scientists, and managers, and at least two types of evidence seem to be consistent with this view. First, there is the well-known fact that labor productivity has increased much more slowly in the United States than in Western Europe or Japan.

Second, the National Science Board has published a study which indicates that the United States originated about 80 percent of the major innovations in 1953-58, about 67 percent of the major innovations in 1959-64, and about 57 percent of the major innovations in 1965-73.³⁴

This unfortunate trend continues. Commerce Secretary Malcolm Baldrige recently commented on the decline in U.S. market competitiveness and spoke of U.S. dominance eroding in steel, automobiles, machine tools and consumer electronics. Whereas a decade ago the U.S. was generating about 70 percent of the world's new technology, this has declined to 50 percent in 1983 and by 1990 may be only 30 percent because of the aggressive efforts by Japanese and other foreign competitors.³⁵

Botkin, et al., add their historical perspective:

. . . in reaction to Sputnik, America launched a buildup of technical education and resources to lead the world in the exploration of space. All these programs, along with the massive infusion

of technical talent from Europe before and during the war, combined to propel America on an unforeseen and revolutionary course of technological development. From this era of government-sponsored research and development emerged the computer, semiconductor, communication, and instrumentation products that today provide the most promising foundation for new economic growth for the rest of this century. By the year 2000, for example, the high tech industry is expected to be second only to energy in its impact on the economy of America and indeed the world.

The United States, having achieved technological leadership and commercial success as an offshoot of these other objectives, has no gameplan to sustain its momentum in high technology. We take our success for granted, not appreciating the underpinnings that have supported our achievements and that will be required to maintain our leadership.³⁶

Mansfield, while recommending increases in technological investment, stresses the need for selectivity:

. . . the available evidence indicates that U.S. exports frequently are based on some form of technological edge over other countries. Also, there is some evidence that this edge has been narrowing. However, from this evidence alone (assuming it is entirely correct), one cannot conclude that a great deal of additional money should be spent on R and D. Whether or not more R and D should be carried out in particular areas depends on the extent of the social payoff there from additional R and D, not on whether or not our technological lead seems to be shrinking in these areas. In other words, it depends on the social rate of return discussed previously.^{37,38}

Public Policy Mechanisms to Stimulate Innovation

If, as follows from the above, the U.S. is in need of increases in R&D investment to stimulate technological innovation, productivity and competitiveness in world trade, what public policy mechanisms seem most appropriate and effective? Most particularly, what lessons are there for NASA policy makers and for U.S. industrialists?

Mansfield gives cautious, qualified answers. He recognizes some underinvestment in civilian technology, attributable to the relatively low rate of private return from a socially-valuable innovation. He also discusses favorably the possible role of the federal government in reducing this underinvestment. Yet, even though some R&D projects that would pay off handsomely to society at large are left unfunded, Mansfield says that economists do not have techniques that are sufficiently precise to indicate how much the federal government should spend on particular kinds of R&D. He gives two guides, however: (a) for a variety of reasons, he guesses that there is a particular need for more long-term, relatively basic R&D projects; here, he comments on the federal government's role in reducing underinvestment; and (b) the decision on whether more R&D should be carried out in particular areas depends on the extent of the social payoff there from additional R&D, not on whether our technological lead seems to be shrinking in these areas. In summary, he indicates a need for more long-term basic research, more R&D in our key R&D intensive industries so that we may maintain our competitive edge, and federal government involvement in reducing underinvestment in civilian technology.³⁹

Christopher Layton, writing from the British perspective, proposes several policy solutions to the more serious problems of the U.K. in sustaining innovation and technological advance. Some of these may be applicable to the U.S. as well. Layton calls for a redirection of qualified scientists and engineers now working in government research laboratories on projects that may yield no immediate practical result to helping industry discover and serve society's needs by, for instance, marketing engineering projects.⁴⁰ Although Layton describes U.K. problems--e.g., national social

values that give low rank to industrial employment and applied research-- that do not apply to a significant extent in the U.S., his call for redeployment of government scientific and engineering expertise to support of industrial technological advance seems to suggest an appropriate solution to certain of our problems.

A second suggestion cited by Layton is attributed to Dr. H.H. Gardner of the British Aircraft Corporation. Gardner proposes that panels be set up in each major industry and closely linked to the universities [which are all government supported] to look at the needs of the next 10 to 20 years and orient university research to fit them. Such an approach would not only make better use of national resources and provide an exciting motivation for university research but would form part of an "education spectrum" in which a researcher would move from industry to a university to obtain a grounding in technology and its relation to society then work on industry-oriented research before returning to an industrial R&D career.⁴¹

Building on this suggestion and incorporating ideas from a U.S. aerospace executive interviewed during this study, it seems possible to create a series of panels of persons involved in major industries, with close links to the space program and to universities, to determine areas of common R&D interest. Such panels could identify areas of high priority in R&D and establish the basis for NASA/industry/university partnerships to work on these.

Secretary Baldrige, in January 1983 congressional testimony, called for revisions in federal antitrust policy to encourage combining expensive research efforts among high technology firms.⁴² That suggestion also

parallels views expressed by industrial R&D managers interviewed for this study, notably senior R&D managers in the automobile industry who deplored the inability to cooperate or even communicate in pollution control research efforts.

Finally, Mansfield discusses critically three kinds of policy mechanisms that have been proposed to help deal with the underinvestment that exists in U.S. civilian technology:

- federal government grants and contracts to industry for more R&D work, presumably R&D with a high social rate of return but an insufficient private rate of return to stimulate private industrial investment in it;
- increased use of federal government laboratories for the conduct of such R&D;
- tax credits for private industry conducting R&D.⁴³

The third of these has become part of the present internal revenue code, despite criticism of it as a policy mechanism:

With regard to tax credits, it is evident that they would reward firms for doing R and D that they would have done anyway, that they would not help firms with no profits, and that they would encourage firms to define R and D as widely as possible. . . . for firms that can appropriate little of the social returns from new technologies, R and D would still be unprofitable even if the tax credit existed.⁴⁴

Another telling criticism of national tax policy is that it aids the capital intensive traditional industries more than high technology firms which look to the equity market rather than to internally generated funds for start-up and expansion capital:

National economic policy, . . . embedded in the new tax laws, provides accelerated depreciation of capital investments, liberalized investment tax credits, and a new twist--"safe harbor leasing"--whereby losing companies can sell their investment tax benefits to profitable ones. . . . this policy reinforces capital intensive "sunset" industries at the expense

of knowledge-intensive "sunrise" industries. Even worse, this policy prolongs the life of dying companies and ignores the needs of growing firms. Scarce capital resources are dissipated, providing marginal returns to the national economy. . . . In the context of tomorrow's economy it makes economic sense to invest more in education than in steel.⁴⁵

The first two of the policy mechanisms suggested above are closely related to the topic of this study. Both types of government-industry partnership to promote socially valuable R&D--increased federal grants and contracts to industry for R&D, and increased use of government laboratories to conduct it--have the potential of stimulating investment in socially desirable R&D and of reducing the time lag between invention and innovation, which averages 10-15 years for major innovations but is shorter for innovations developed with government funds than with private funds.⁴⁶

Mansfield's discussion of the shortcomings of these two policy mechanisms (which is not to say that he disapproves of them) relates to the problems of central planning, which is as difficult in R&D management as it has proved to be in the national economic management of socialist countries.

With regard to grants and contracts, as with any selective mechanism, one runs into the problem that benefits and costs of various kinds of R and D are very hard to forecast. As we have seen, even major corporations have difficulties using various forms of cost-benefit analysis for R and D project selection, although they have a benefit concept that is much easier to estimate than most government agencies do. . . . Further, . . . such estimates may be biased for parochial, selfish, or political reasons, the result being a distortion of social priorities, if the estimates are taken seriously.

With regard to the increased use of government laboratories to promote civilian technology, our results . . . suggest the problems in having R and D conducted by organizations that are not in close touch with the marketing and production

of the product. It is very important that there be unimpeded flows of information and good coordination of R and D, on the one hand, and marketing and production on the other. Otherwise, the R and D is likely to be misdirected, or even if it is not, it may be neglected or resisted by potential users. . . . this is a difficult problem for various divisions of a firm, and it would seem to be made worse if the R and D is done in government laboratories. In the last decade, many governments have tended to convert government laboratories and to increase the amount of government financed R and D done in industrial firms in order to bring R and D into closer contact with application and commercialization.⁴⁷

Nevertheless, Mansfield seems to agree with Eads and Nelson that there is an appropriate role for the federal government, in partnership with industry, to fund and conduct research of manifest social benefit. This can be done, Eads and Nelson point out, by continuing some successful R&D policies of the past--notably the NACA policies of the 1920s and 1930s--rather than in programs such as the breeder reactor in which the federal government acts to an unprecedented extent to fund and control the development of products for production and sale by private companies through the market.⁴⁸

Eads and Nelson point out that the federal government has historically, with few exceptions, avoided supporting or conducting R&D aimed specifically at improving particular classes of products or services which normally are sold to the public through the marketplace. Exceptions have been products or services of merit to the general welfare (e.g., R&D on health related products; cures for dread diseases), or products involving large fractions of society as producers (e.g., agricultural research to benefit farmers), or products closely linked with national defense (e.g., aviation development). ". . . by and large in all of these cases public funds tended to go into research and exploratory development, with commercial development being left to private initiative."⁴⁹

The pre-1960 public support of research relevant to civil aviation is directly relevant. In 1915 the National Advisory Committee on Aeronautics (NACA) was created to spur the development of American aviation. During its heyday during the 1920s and 1930s, NACA pioneered in the development and operation of R and D facilities for general use (wind tunnels, for example), in information collection and dissemination, and in basic research and exploratory development. It undertook major work on aircraft streamlining, design of engine parts, properties of fuels, and structural aspects of aircraft design, and it built and tested a variety of experimental hardware. But NACA did not directly support the development of particular commercial airplanes. Indeed, the idea that such a role should be assumed by the federal government was explicitly rejected . . .⁵⁰

The conclusion of Eads and Nelson is that the federal government is most successful and is following sound precedent when it avoids distorting the traditional decentralized modes of R&D organization, decision-making and risk-taking, by attempting to install a more concentrated and detailed central planning structure. Instead, as in NACA's support of basic research and exploratory developments, public funding in the early stages of the R&D process can be expected to spur private development spending by making clearer the development options and reducing the cost of the developments needed to achieve a given performance enhancement.⁵¹

This approach, which stimulates private R&D spending in socially valuable fields yet avoids the dangers of overcentralized control and federal subsidy in the production of private marketplace products, appears to offer promise to U.S. policymakers searching for the best public policy mechanisms to revitalize U.S. technological innovation and the national economy so dependent upon it.

FOOTNOTES

1. Mansfield, Edwin, "The Process of Technical Change," in Economics of Research and Development, Richard A. Tybout, ed., Columbus, Ohio: Ohio State University Press, 1965, p. 136.
2. Press, Frank, U.S. Senate, Committee on Commerce, Science and Transportation, Subcommittee on Science, Technology and Space, Oversight of Science and Technology Policy, hearings held February 10 and April 26, 1978, Washington, D.C.: Government Printing Office, 1978, p. 132.
3. Mansfield, Edwin, Industrial Research and Technological Innovation: An Econometric Analysis, New York: W.W. Norton, 1968, p. 4.
4. Mansfield, Edwin, testimony before the U.S. House, Committee on Science and Technology, Subcommittee on Domestic and International Scientific Planning and Analysis, in Federal Research and Development Expenditures and the National Economy, hearings held April 27, 28, 29, and May 4, 5, 1976, Washington, D.C.: Government Printing Office, 1976, p. 49.
5. Mansfield Edwin, "Contribution of R&D to economic growth in the United States," Science, Vol. 175, February 4, 1972, p. 478.
6. Freeman, Christopher, The Economics of Industrial Innovation, Baltimore, MD: Penguin Books, 1974, pp. 339-340.
7. Ibid., pp. 386-387.
8. Mansfield, Edwin, et al., The Production and Application of New Industrial Technology, New York: W.W. Norton, 1977, pp. 190-192.
9. Mansfield, op. cit., 1976, pp. 40-40 and 46-48.
10. Mansfield, op. cit., 1977.
11. Ibid.
12. Mansfield, op. cit., 1965, p. 140.
13. Mansfield, op. cit., 1977, p. 3.
14. National Science Foundation data quoted in Mansfield, op. cit., 1968, p. 7.
15. Mansfield, op. cit., 1972, p. 480.
16. Mansfield, op. cit., 1968, p. 18.
17. Mansfield, op. cit., 1977, p. 3.
18. Ibid.

19. Layton, Christopher, Ten Innovations: an International Study on Technological Development and the Use of Qualified Scientists and Engineers in Ten Industries, New York: Crane, Russak and Company, 1972.
20. Mansfield, op. cit., 1968, p. 84.
21. Mansfield, op. cit., 1977, p. 3.
22. Mansfield, Edwin, "Basic Research and Productivity Increase in Manufacturing," American Economic Review, Vol. 70, No. 5, December 1980(d), p. 869.
23. Ibid., pp. 871-872.
24. Botkin, James, et al., Global Stakes: The Future of High Technology in America, Cambridge, MA: Ballinger Publishing, 1982.
25. Mansfield, op. cit., 1972, pp. 479 and 485.
26. Braunstein, Yale M., William J. Baumol, and Edwin Mansfield, "The economics of R&D," in Management of Research and Innovations, B.V. Dean and J.L. Goldhar, New York: North-Holland Publishing Company, 1980, p. 28.
27. Mansfield, op. cit., 1976, p. 51.
28. Mansfield, Edwin, testimony before the U.S. House, Committee on Science and Technology, in Seminar on Research, Productivity and the National Economy, Washington, D.C.: Government Printing Office, June 18, 1980(a), p. 15.
29. Mansfield, Edwin, "Research and development, productivity and inflation," Science, Vol. 209, September 5, 1980(b), pp. 1091-1092.
30. Ibid., p. 1092.
31. Mansfield, Edwin, "Technology and technological change," Economic Analysis and the Multinational Enterprise, John H. Dunning, ed., London: George Allen and Unwin, Ltd., 1974, pp. 156-158.
32. Mansfield in U.S. Senate, op. cit., p. 159.
33. Mansfield, op. cit., 1980(a), p. 9.
34. Ibid.
35. From Baldrige's testimony before the U.S. Senate Finance Committee, quoted in "Aid high-tech firms, Baldrige says," Rocky Mountain News, January 20, 1983, p. 25.
36. Botkin, et al., op. cit., p. 3.
37. Mansfield, op. cit., 1976.

38. Mansfield et al., op. cit., 1977, pp. 210-211.
39. Mansfield, op. cit., 1980(a), pp. 10-11.
40. Layton, op. cit., pp. 25-26.
41. Ibid., p. 29.
42. Baldrige, op. cit.
43. Mansfield, op. cit., 1977, pp. 194-195.
44. Ibid., p. 195.
45. Botkin et al., op. cit., pp. 3-4.
46. Mansfield, op. cit., 1968, p. 129.
47. Mansfield et al., op. cit., 1977, pp. 194-195.
48. Eads, George, and Richard R. Nelson, "Governmental support of advanced civilian technology: power reactors and the supersonic transport," Public Policy, Vol. 19, No. 3, Summer 1971, pp. 405-407.
49. Ibid., p. 407.
50. Ibid.

REFERENCES

- "Aid high-tech firms, Baldrige says," 1983, Rocky Mountain News, January 20, 1983.
- Botkin, James, et al., 1982, Global Stakes: The Future of High Technology in America, Cambridge, MA: Ballinger Publishing, 1982.
- Braunstein, Yale M., William J. Baumol, and Edwin Mansfield, 1980, "The economics of R&D," in Management of Research and Innovation, B.V. Dean and J.L. Goldhar, New York: North-Holland Publishing Company, 1980.
- Eads, George and Richard R. Nelson, 1971, "Governmental support of advanced civilian technology: power reactors and the supersonic transport," Public Policy, Vol. 19, No. 3, Summer 1971, pp. 405-427.
- Freeman, Christopher, 1974, The Economics of Industrial Innovation, Baltimore, MD: Penguin Books, 1974.
- Gurwitz, Aaron S. 1981. "The new faith in high tech," Wall Street Journal, October 27, 1982.
- Layton, Christopher, 1972, Ten Innovations: An International Study on Technological Development and the Use of Qualified Scientists and Engineers in Ten Industries, New York: Crane, Russak and Company, 1972.
- Mansfield, Edwin, 1965, "The process of technical change," in Economics of Research and Development, Richard A. Tybout, ed., Columbus, Ohio: Ohio State University Press, 1965.
- Mansfield, Edwin, 1968, Industrial Research and Technological Innovation: An Econometric Analysis, New York: W.W. Norton, 1968.
- Mansfield, Edwin, et al., 1971, Research and Innovation in the Modern Corporation, New York: W.W. Norton, 1971.
- Mansfield, Edwin, 1972, "Contribution of R&D to economic growth in the United States," Science, Vol. 175, February 4, 1972, pp. 477-486.
- Mansfield, Edwin, 1974, "Technology and technological change," in Economic Analysis and the Multinational Enterprise, John H. Dunning, ed., London: George Allen and Unwin, Ltd., 1974.
- Mansfield, Edwin, 1976, Testimony before the U.S. House, Committee on Science and Technology, Subcommittee on Domestic and International Scientific Planning and Analysis, in Federal Research and Development Expenditures and the National Economy, Hearings held April 27, 28, 29; May 4, 5, 1976, Washington, D.C.: Government Printing Office, 1976.
- Mansfield, Edwin, et al., 1977, The Production and Application of New Industrial Technology, New York: W.W. Norton, 1977.
- Mansfield, Edwin, Anthony Romeo, and Samuel Wagner, 1979, "Foreign trade and U.S. research and development," Review of Economics and Statistics, Vol. 61, No. 1, February 1979, pp. 49-57.

Mansfield, Edwin, 1980a, Testimony before the U.S. House, Committee on Science and Technology, in Seminar on Research, Productivity and the National Economy, June 18, 1980, Washington, D.C.: Government Printing Office, 1980.

Mansfield, Edwin, 1980b, "Research and development, productivity, and inflation," Science, 209, September 5, 1980, pp. 1090-1093.

Mansfield, Edwin, 1980c, Market Structure, International Technology Transfer, and the Effects on Productivity of the Composition of R&D Expenditures: Executive Summary, Philadelphia, PA: University of Pennsylvania, 1980.

Mansfield, Edwin, 1980d, "Basic research and productivity increase in manufacturing," American Economic Review, Vol. 70, No. 5, December 1980, pp. 863-873.

Mansfield, Edwin, 1981, "How economists see R&D," Harvard Business Review, Vol. 59, No. 6, November/December 1981, pp. 98-106.

"Monsanto is mining Europe's high-tech lode," Business Week, August 16, 1982.

Twiss, Brian C., 1974, Managing Technological Innovation, London: Longman, 1974.

U.S. Central Intelligence Agency, 1982, Economic and Energy Indicators, Washington, D.C., April 2, 1982.

U.S. Senate, Committee on Commerce, Science and Transportation, Subcommittee on Science, Technology and Space, 1978, Oversight of Science and Technology Policy, Hearings held February 10 and April 26, 1978, Washington, D.C.: Government Printing Office, 1978.

APPENDIX B

The Development of NASA's Technology Transfer Program

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THE DEVELOPMENT OF NASA'S TECHNOLOGY TRANSFER PROGRAM

NASA's technology transfer program was instituted some 20 years ago. In the following discussion, the legislative basis for NASA's technology transfer activities is briefly examined; the institutional development of NASA's Office of Technology Utilization (TU) is traced; the technology transfer programs that the TU Office has undertaken are described; and, an assessment of NASA's current technology transfer program is provided.

The Legislative Basis for Technology Transfer

The National Aeronautics and Space Act of 1958 set out eight objectives for the newly created space agency; among them were two that related to technology transfer. First and foremost, NASA was to contribute to ". . . the expansion of human knowledge of phenomena in the atmosphere and space."¹ It was the fourth objective which included technology transfer. It started as one of NASA's missions ". . . the establishment of long-range studies of the potential benefits to be gained from, the opportunities for, and the problems involved in the utilization of aeronautical and space activities for peaceful and scientific purposes."²

Technology transfer was more specifically addressed in the description of the agency's functions. Three functions were set out in the law. The first was to conduct aeronautic and space activities; the second was to provide a mechanism for conducting scientific measurements and observations in space. The agency's third function was ". . . to provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."³

Two observations are in order. First, the transfer of technology was not explicitly established as the agency's primary objective or function. In fact, it would be considered of secondary importance to the first goal: the exploration of space.

Second, the legislation charged NASA with a task (i.e., technology transfer) which was relatively unprecedented as a formal government function. Technology transfer had been occurring informally between government, industry, the universities and the public for years, but no agency prior to NASA had such a clear, emphatic mandate to pursue this task in a programmatic way.

An Institutional Approach to Technology Transfer

The informal transfer of technology from NASA to industry and the public would have occurred with or without a formal technology transfer program. People talking to people, NASA engineers taking new jobs, and NASA scientists publishing scholarly articles are means of technology transfer which do not depend on an established program to disseminate information. Indeed, it is likely that much, if not most, technology transfer occurs serendipitously through informal means.

Furthermore, many of NASA's technology transfer activities may be categorized as instances of direct application. For example, through its LANDSAT program, NASA makes its satellite technology available for surveying the earth's resources. The resulting information can be used for such purposes as agricultural crop forecasting, rangeland and forest management, and mineral exploration.

While informal transfer and direct application are important components of the dissemination of NASA technology, this discussion focuses upon NASA's formal program for "horizontal" technology transfer. Horizontal transfer occurs when technical information is generated within one context and applied in a different context.⁴ Since 1963, the Technology Utilization (TU) Program has been the entity responsible for the formal transfer of NASA technology such as the use of aerospace technology for medical applications.

A brief institutional history. The NASA technology transfer program was drawn from various offices, under different program titles. By 1963 the Office of Policy Analysis included the Technology Utilization Program. In 1966 an Office of the Assistant Administrator for Technology Utilization was created. During the early 1970s, the TU Program was under the Assistant Administrator for Industry Affairs, and the program's administration was the sole responsibility of an office with director-level status. When the shift was made to the Office of Space and Terrestrial Applications in 1977 the director of the TU Program was given other program areas to supervise, which, in effect, lowered the status of the program within the NASA hierarchy. For the first time the TU Program was included in one of NASA's major mission areas, whereas formerly it had been considered part of NASA's support functions. To some extent, this move may have isolated the TU Program from the other mission areas, which it was also intended to serve. When it was placed under the aegis of the Office of External Relations in 1980 and again directly linked with Industry Affairs, the TU Program was once more formally recognized as a support function.

One indicator of the TU Program's evolution as a formal institution is its historic levels of funding. This information is provided in Table 1.

Annual appropriations for the TU Program remained between \$3.8 and \$5.5 million from 1964 to 1975. Between 1975 and 1980, appropriations for the program doubled. In 1981, however, program appropriations were cut by 25 percent.

In constant dollars, appropriations for the program have dropped 35.8 percent from their peak in 1980. In fact, after adjusting for inflation, 1982 and 1983 are revealed as the years of lowest funding since 1963.

As might be expected, these reductions have renewed an interest in cost control and productivity among the TU Program administrators. In fact, the reductions may have accelerated a trend which has characterized the development of the TU Program: an evolution from an experimental to a more established approach to transferring technology.

It was widely recognized during the sixties that, in order to transfer technology, it was necessary first to learn more about the technology transfer process. This was to be accomplished through experimentation. Witness the comments of the Senate Committee on Aeronautical and Space Sciences in its FY 1967 authorization for NASA:

"The Committee, as it has in previous years, fully supports the concept of the program (the TU Program). It recognizes, however, that it is still highly experimental and, based upon an analysis of the individual elements, the Committee believes the program should be maintained at a level essentially consistent with the previous 2 fiscal years."⁵

When Deputy Administrator Robert C. Seamans, Jr., was asked the purpose of the \$5 million authorization for technology utilization in FY 1968, he replied, "The basic purpose of the \$5 million item is to, you might say, experiment with the processes involved in making technological and scientific information available to all sectors of the United States."⁶

TABLE 1
 LEVELS OF FUNDING AUTHORIZATION FOR THE NASA
 TECHNOLOGY UTILIZATION PROGRAM, FY 1963-1983.
 (In THOUSANDS OF DOLLARS)

YEAR	ACTUAL DOLLARS*	CONSTANT DOLLARS**
1963	\$ 866	\$ 2,727
1964	3,080	9,575
1965	3,850	11,767
1966	3,900	11,588
1967	4,000	11,553
1968	3,800	10,533
1969	3,800	9,996
1970	5,000	12,417
1971	4,000	9,524
1972	5,000	11,525
1973	4,000	8,680
1974	4,500	8,799
1975	5,500	9,854
1976	7,500	12,705
1977	8,100	12,889
1978	9,100	13,451
1979	9,100	12,089
1980	11,980	14,020
1981	8,800	9,330
1982	8,000	8,000
1983	9,000	9,000

*Data for 1963-1969 have been adjusted to exclude authorizations for policy analysis.

**Historic data adjusted to 1982 dollars using the Consumer Price Index.

Source: NASA

Through experimentation, NASA programs for technology transfer evolved as established, ongoing institutions. In April of 1969, Richard L. Lesher, Assistant Administrator for Technology Utilization, reported, "The foundations of the Technology Utilization Program have become stabilized."⁷ By 1978, Louis Mogavero, Director, Technology Utilization Office, could report ". . . the program has now achieved a significant level of maturity in technology transfer," but he was quick to point out that ". . . we are still not satisfied that the mechanics of the process are fully understood."⁸

NASA administrators are not likely ever to be "satisfied" with their understanding of a process as amorphous as technology transfer. Nevertheless, over the course of twenty years, the agency has developed an institutional approach to transferring technology, and these programs have experienced some success in accomplishing this task. The development of these programs is the subject of the next subsection.

The NASA Technology Transfer Programs

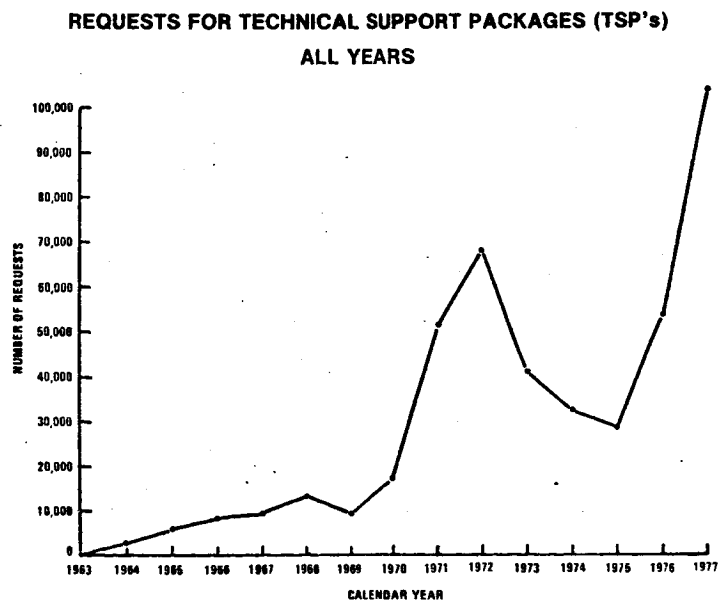
Publications. Since its early years, the TU Office has conceived of technology transfer as consisting of three functions: technology identification, evaluation, and dissemination. In the early sixties, Technology Utilization Officers opened offices in each of the NASA field installations in order to monitor innovations and advances in NASA technology and to review contractor reports of innovation. These contractor reports are required by the National Aeronautics and Space Act of 1958, Section 305(b). There is also a New Technology Clause incorporated in NASA contracts requiring that the contractor search for and report all new technology resulting from work under the contract. These New Technology Reports were forwarded to an independent research institute, which was responsible for evaluating the technology for its commercial potential.

B-7

If evaluation revealed that an innovation had potential for commercial application, information on the new technology was then disseminated through NASA publications. The best known of these publications, NASA Tech Briefs, is still in use. NASA Tech Briefs serves as an announcement bulletin by providing a one or two page description of an innovation. Various compilations and elaborations of NASA Tech Briefs have been developed to provide more comprehensive information on topics of interest. One of these is the Technical Support Package (TSP), which provides backup information for the material initially reported in Nasa Tech Briefs.

The number of requests for publications provide one measure of the performance of the NASA publications program. A graph of requests for TSPs is provided in Figure 1.

FIGURE 1



Source: Hearings Before the Subcommittee on Science, Technology and Space. NASA Authorization for Fiscal Year 1979. March 1 and 7, 1978. p. 555.

While the increase in requests has not been steady, the figure does show the number of requests surpassing 100,000 in 1977, an indication of substantial interest in NASA publications. In 1979, NASA reported that requests for new subscriptions to the NASA Tech Briefs were averaging 1,300 a month.⁹

The NASA publications program has not been problem free however. Since the program's inception, one problem has been to motivate innovators to report their findings to the TU office. Without their help in identifying new technologies, the first step in the transfer process is impeded. Leshner expressed the problem as follows: "the aim, of course, is to achieve a condition where scientists and engineers accept responsibility for the documentation and reporting of their R&D results in the same spirit that they accept responsibility for the R&D itself."¹⁰

This condition does not tend to occur naturally with NASA employees and contractors, even though new technology reporting is required. Some scientists and engineers, dedicated to the agency's primary mission of space exploration, may regard technology reporting as an unnecessary bother. NASA has attempted to address this problem by streamlining the documentation process and by rewarding technology reporting with recognition and monitoring awards. As of 1982, 80 percent of the New Technology Reports were the result of contractor work, while the remaining 20 percent were attributable to NASA employees.¹¹

Of course, the problem of technology reporting is not unique to the publications program. It can crop up in any of the programs for NASA technology transfer, but it is most evident in the publications program which depends for its success on the volume of information generated.

Indeed, the very volume of information published is another of the problems encountered by the publication's program. As Harvey Brooks has written, "the problem is not so much access to information as it is identification of relevant information."¹² While publications provide an inexpensive means of disseminating information to a broad audience, the recipient may feel overloaded with information. Lacking the time to read and evaluate each of the publications NASA sends him, the potential user may fail to notice the publication that is particularly relevant to his needs.

The Dissemination Centers. The TU Office recognized the limitations of publications as a means for technology transfer. There was a need to assist the potential user in finding the information relevant to his needs. To this end, NASA initiated a program to provide clients with computerized searches of the NASA data bank. The institutions for providing these services were named Regional Dissemination Centers (RDCs), later to be called Industrial Applications Centers (IACs). The first of these centers was established at Indiana University in 1963.

The success of the RDC at the University of Indiana, and of its predecessor, a pilot project at the Midwest Research Institute, led to the creation of more RDCs/IACs in the following years (see Table 2). In 1965, four RDCs were in operation. By 1967, twice that number were operating. Through most of the 1970s, six RDCs/IACs were in business.

The dissemination center program has been characterized by changes and experimentation. For example, one of the RDCs, Project ASTRA (Applied Space Technology-Regional Advancement) at the Midwest Research Institute, began as an effort to identify NASA technology which could be used by mid-western companies for new product development or in process improvement

efforts. In 1963, the program was modified to experiment in technology dissemination by mail and telephone. Its purpose was to provide rapid response information on specific technical advances that midwestern firms found interesting. In 1966, ASTRA switched from providing free services to charging fees, and in 1967, it added retrospective searching and custom interest profile services. In 1968, this RDC was phased out of existence.

Over the course of its dissemination center program, NASA has experimented with ways to expand the RDC/IAC information base, reach new groups of users, and improve the services offered. Developments in each of these areas are discussed below.

Through NASA's efforts, the centers' information base has grown into one of the world's largest repositories of technical data, including information from the Department of Defense and articles from scholarly journals as well as NASA technical data. Recognizing that its computer programs are a valuable type of information in themselves, NASA opened the Computer Software Management and Information Center (COSMIC) at the University of Georgia in 1966. Although not technically an IAC, COSMIC provides interested users with access to NASA and other agency computer programs in much the same way an IAC provides access to technical articles.

Attracting new users has always been one of the biggest concerns for the dissemination center program. Early in the program, George S. Simpson, Jr., Assistant Administrator for Technology, Utilization and Policy Planning, described the purpose of the RDC as ". . . to make the total of NASA scientific and technical information available on a local basis, so that the private user can come directly into contact with it in a routine fashion." ¹³ While the RDCs/IACs have been distributed geographically around the country, they have never been "local" sources of information for the majority of potential users. Six or eight centers cannot be expected to provide a high level

TABLE 2
NASA REGIONAL DISSEMINATION CENTERS

Name	Organization	Location	Began Full Operation
Aerospace Research Applications Center (ARAC)	Indiana University	Bloomington, Indiana	September 1963
Center for Application of Sciences & Technology (CAST)	Wayne State University	Detroit, Michigan	July 1964
Knowledge Availability Systems Center (KASC)	University of Pittsburgh	Pittsburgh, Pennsylvania	September 1964
New England Research Application Center (NERAC)	University of Connecticut	Storrs, Connecticut	July 1967
North Carolina Science & Technology Research Center (NC/STRC)	Research Triangle Institute	Research Triangle Park, North Carolina	November 1964
Project ASTRA	Midwest Research Institute	Kansas City, Missouri	May 1962
Technology Application Center (TAC)	University of New Mexico	Albuquerque, New Mexico	March 1966
Western Research Application Center (WESRAC)	University of Southern California	Los Angeles, California	April 1967
Kerr Industrial Applications Center (KIAC)	Southeastern Oklahoma State University	Durant, Oklahoma	July 1978

of local accessibility. To illustrate this point, consider the RDC/IAC in comparison to another well known information dissemination system: the Department of Agriculture's county extension agents. While a county agent is truly available on a local level, the closest IAC is often located far from the potential user. In fact, potential users often are not aware of the existence of NASA dissemination centers.

NASA has undertaken several measures to address this problem. In the mid seventies, it established outreach offices for the IACs in highly urban areas, such as San Francisco, Chicago, and Dallas. The personnel at these offices acted as "sales agents" to identify potential customers and provide them with access to an IAC outside their immediate geographic area. Furthermore, the agency placed representatives of the IACs at selected NASA field centers to coordinate technical responses to customer inquiries. NASA placed advertisements in periodicals to expand the public's awareness of the availability of NASA technical information. In cooperation with other government agencies, such as the Small Business Administration. NASA also sponsored conferences on seminars which publicized NASA's technology transfer programs. Despite these efforts, customer awareness remains one of the biggest problems for the IAC program.

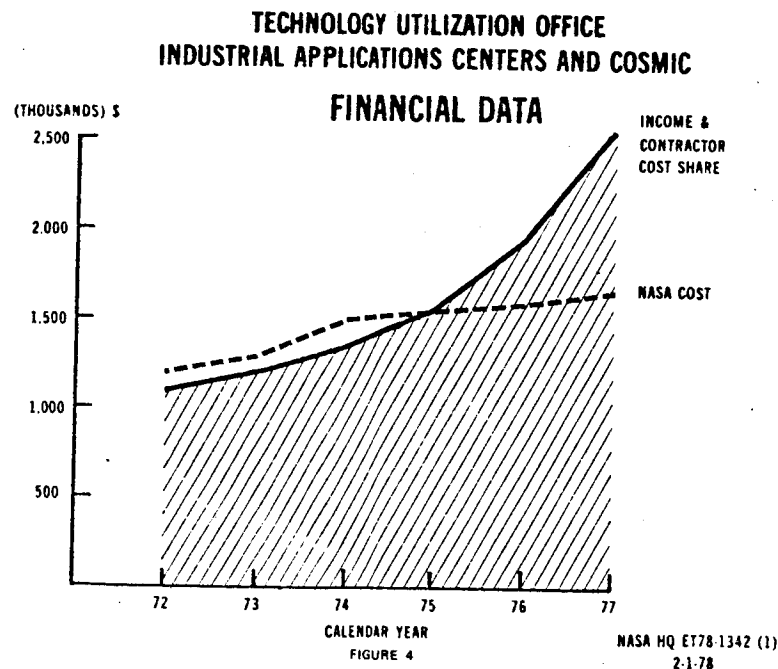
NASA also has taken steps to expand its customer base by using existing mechanisms to identify state and local government and industrial clients. Experimental programs were launched in FY 1977 to establish state applications centers in conjunction with the Universities of Florida and Kentucky. These programs operated much like IACs to provide technical assistance on a state and local level, but they concentrated on a particular state instead of a region, and they focused on small businesses and less industrialized areas.

In addition to expanding its information and customer base, the dissemination center program sought to improve the quality of its services by emphasizing personal contact at the RDCs/IACs. IAC applications engineers were appointed to assist the user in defining his problem and interpreting the information uncovered by the computer bank search. The applications engineer also serves as a liaison between the user and NASA, providing the user with a means of pursuing more detailed information on a topic of interest.

In a 1969 evaluation of the University of New Mexico's Technology Application Center (TAC), the Denver Research Institute concluded that this RDC's services were of "substantial value" to researchers.¹⁴ A 1977 study by Mathtech, Inc. found that the benefits of COSMIC outweighed its costs by a ratio of four to one.¹⁵

For the program as a whole, one measure of its performance is the level of industrial contributions received. This assumes that the level of contributions provides an indication of the value industry ascribes to the services provided. Figure 2 was presented before the U.S. Senate in 1978. It shows that in 1975, income from industry and contractor cost sharing surpassed NASA's costs in supporting the IACs and COSMIC.

FIGURE 2



Source: NASA

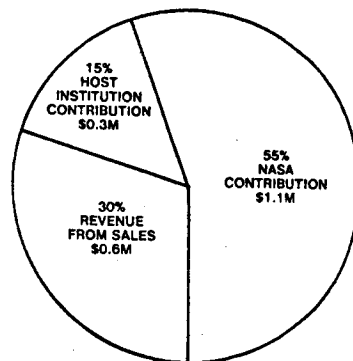
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Figure 3 provides a comparison of revenue sources for the dissemination centers in 1972 and 1978. By 1978, the users' share of the total budget had climbed to 52 percent, up from 30 percent in 1972. While these data provide evidence of progress in soliciting user support, it is noteworthy that the centers are not self supporting.

FIGURE 3

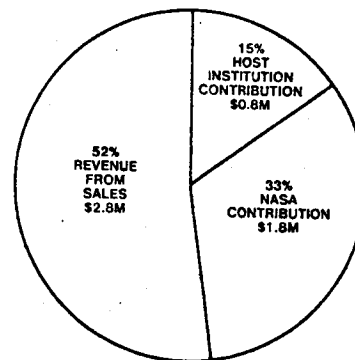
REVENUE SOURCES FOR DISSEMINATION CENTERS

INCLUDES: INDUSTRIAL APPLICATION CENTERS
STATE APPLICATION CENTERS
COMPUTER SOFTWARE MANAGEMENT
INFORMATION CENTER



1972

TOTAL OPERATING BUDGET: \$2.0M



1978

TOTAL OPERATING BUDGET: \$5.4M

Source: NASA

Applications Teams. In recognition that technology is transferred most effectively through personal contact, NASA launched an experimental effort in 1967 to promote the application of NASA technology to the biomedical field through the participation of multidisciplinary teams. These teams, known as Biomedical Applications Teams, or BATEams, were formed at three independent research institutes to assist biomedical researchers in identifying problems impeding their research. Once a problem was identified, the BATEam would describe it in a "Problem Abstract," conduct a computerized search for relevant information in the NASA data bank, and circulate the "Problem Abstract" to NASA laboratories to see whether NASA scientists and engineers were aware of potential technological solutions for the problem.

The success of the original BATEams led to the creation of additional teams in later years. In all, nine teams were created, seven of which were in operation in 1981. These included BATEams and Technology Application Teams (TATEams). The TATEams worked in the same manner as the BATEams, but concentrated on different areas of interest. TATEams have applied their expertise in fields such as air and water pollution, transportation, and mine safety.

With the budget cuts of 1981, the number of applications teams was reduced from seven to two. Compared to the publications program, the applications team program requires a higher level of funding per contact with potential users. However, the ratio of successful transfers to the number of contacts is higher for the applications teams. This is because the applications teams offer the benefits of personal contact, which include quick response to user questions and commitment to overcoming the barriers to transfer. In short, the applications teams provide champions or catalysts for change who will actively promote technology transfer.

Personal involvement with technology transfer not only affects the success of the transfer, but also the types of transfer which occur. It has not always been clear why NASA has pursued transfers in particular fields. As often as not, the areas of transfer seem to reflect the interests and know-how of the transfer agents as much as any defined agency objective.

Applications Projects. Applications projects go one step beyond the identification of problems and potential solutions. Daniel J. Harnett, then Assistant Administrator for Industry Affairs and Technology Utilization, raised the concept of applications projects in testimony before the U.S. Senate in 1971:

" . . . We are re-examining our program objectives. In general, we receive, process, and disseminate technology but stop there, at the point at which we make it available to others. It may now be feasible for us to more actively pursue adaptation, adoption, and utilization by closing the gap between creating an awareness of new technology and putting it to work in another sector."¹⁶

In technology applications projects, NASA actually develops a prototype that can be tested and demonstrated for its usefulness. An applications project may be initiated by a request from a government agency, the efforts of a NASA technologist, or through the work of an applications team.

By their very nature, the applications projects tend to be ad hoc efforts. They are an expensive but effective means of transfer, which relies on a change advocate or champion to accomplish the technology application. In its 1977 analysis of selected applications projects, Mathtech found the benefits of these projects to consistently outweigh their costs.

NASA's Technology Utilization Program Today

In its present form, the NASA TU Program is the embodiment of lessons learned, administrative priorities, and financial constraints. Through experimentation with technology transfer, NASA has developed a better (but by no means complete) understanding of how the process can be promoted in a programmatic way. In the TU Program's fifth year of operation, Leshner summarized some conclusions about technology transfer and the TU Program. Several of these lessons are particularly relevant to the present discussion:

- ". . . technology utilization must be viewed as a mission for the entire institution, not as a separate secondary effort.
- . . . a technology utilization program must be geared to the provision of services, not just abstracts, indexes, or documents.
- . . . all services must have built-in measures of effectiveness--and, for us, the marketplace has proved the most effective measure." 17

By these standards, the TU Program in its present form is neither a complete success nor a failure. Institutionally, the TU Program usually has been positioned within the administrative structure of NASA in such a way that it can serve all the major mission areas. However, the TU Program, the TU Officers, New Technology Reporting, and applications projects are still largely regarded as a "separate, secondary effort." The TU Program has gone beyond the provision of abstracts and documents to the provision of services, but these activities have been constrained by budget considerations. While NASA has measured its program in the marketplace and documented increases in requests for publications and user financial support, its IAC program has not achieved self sufficiency, the ultimate measure of acceptance in the marketplace.

It is in the provision of services, "not just abstracts, indexes, or documents," that the development of the TU Program has been most noteworthy. The use of applications engineers at the IACs, the work of the applications teams, and the successful applications projects reflect the most innovative approaches NASA has taken to technology transfer. These measures reflect NASA's conviction that technology transfer includes ". . . working continually with potential users to identify technological demands or needs; creating an infrastructure of problem-solving transfer agents or gate keepers; and perhaps most importantly, serving as champions and catalysts of the technology transfer process itself." ¹⁸

These types of measures also are the most expensive in terms of cost per user contacted. As such, they are vulnerable to budget cuts and perhaps are more dispensable than the publications program. In times of significant budgetary constraints, publications provide a way of making information available to a wide audience at a relatively low cost. Whether a transfer is actually accomplished, however, will depend on the initiative of the potential user to find the right information, get his questions answered, and hurdle the obstacles of application.

Today the TU Program depends on four methods to promote technology transfer: (1) publications, (2) dissemination centers, (3) applications teams, and (4) applications projects. Experimentation within the program has been slowed by budget constraints as well as the natural formalization of the program over time. The level of activity (such as the number of applications teams in operation) has been reduced due to fiscal considerations. In light of funding restraints, the program's present challenge is to maximize the effectiveness of its efforts so that progress continues in making transfers as well as in learning about the technology transfer process itself.

FOOTNOTES

- 1 National Aeronautics and Space Act of 1958. Sec. 102(c)(1).
- 2 Ibid, Sec. 102(c)(4).
- 3 Ibid, Sec. 203(a)(3).
- 4 National Science Foundation. Technology Transfer and Innovation 1966.
- 5 Committee on Aeronautical and Space Sciences, U.S. Senate. NASA Authorization for Fiscal Year 1967. May 23, 1966. p. 72.
- 6 NASA Authorization for Fiscal Year 1968. April 18, 19 and 20. p. 142.
- 7 NASA Authorization for Fiscal Year 1970. April 28-30, 1969, p. 62.
- 8 NASA Authorization for Fiscal Year 1979. March 1 and 7, 1978, p. 568.
- 9 NASA Authorization for Fiscal Year 1980. March 2, 14, 15, May 1, and June 4, 1979. p. 1358.
- 10 NASA Authorization for Fiscal Year 1969. February 27-29, 1968. p. 80.
- 11 Private Sector Involvement in the NASA Technology Utilization Program: A report to the Committee on Science and Technology, U.S. House of Representatives and to the Committee on Commerce, Science and Transportation, U.S. Senate. February 1982.
- 12 Harvey Brooks. "National Science Policy and Technology Transfer." Technology Transfer and Innovation. National Science Foundation. 1966.
- 13 NASA Authorization for Fiscal Year 1965. March 4-6, 9, 16-18, 1964. p. 425.
- 14 Denver Research Institute. A User's Evaluation of a NASA Regional Dissemination Center. May 1969.
- 15 Mathtech Inc. A Cost Benefit Analysis of Selected Technology Utilization Office Programs. November 7, 1977.
- 16 NASA Authorization for Fiscal Year 1972. March 30 and April 1, 1971, p. 24.
- 17 NASA Authorization for Fiscal Year 1969. February 27, 28, and 29, 1968, p. 86.
- 18 Edward Z. Gray, Assistant Administrator for Industry Affairs and Technology Utilization. NASA Authorization for Fiscal Year 1976. February 6, 18, 19 and March 3, 11, and 13, 1975. p. 322.

APPENDIX C

Factors Enhancing the Competitive Posture of
Foreign High Technology

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FACTORS ENHANCING THE COMPETITIVE POSTURE OF
FOREIGN HIGH TECHNOLOGY

I. INTRODUCTION

Anyone watching the trends in international trade over the last two decades knows that the United States is playing a proportionately smaller role in the world economy. For example, a recent analysis by the Office of Foreign Economic Research, Bureau of International Labor Affairs, U.S. Department of Labor, found that U.S. export shares between 1970 and 1977 for 102 manufactured commodities had trend declines in 71% of these commodities compared to 26% for Japan and 24% for West Germany.¹ Furthermore, an analysis of U.S. export performance in third country markets compared to that of Japan, the U.K., West Germany, and France showed that, of the top 17 U.S. export commodities, all 17 showed losses to these competitors between 1970 and 1977.

Certain agricultural products, and high technology products, such as aircraft, computers, chemicals, and machinery products traditionally have been a source of strength in the U.S. trade balance. The U.S. dominance in world trade of high technology markets is being rapidly eroded, however, to the point that (third country markets aside) there is increased competition from foreign producers in the U.S. domestic market. This is particularly significant because these are among the sectors of the U.S. economy which contribute the most to productivity growth, to holding down inflation, and to creating jobs. (In fact, a recent U.S. Department of Commerce report showed that high technology companies created jobs 88% faster than other businesses between 1957 and 1973.²)

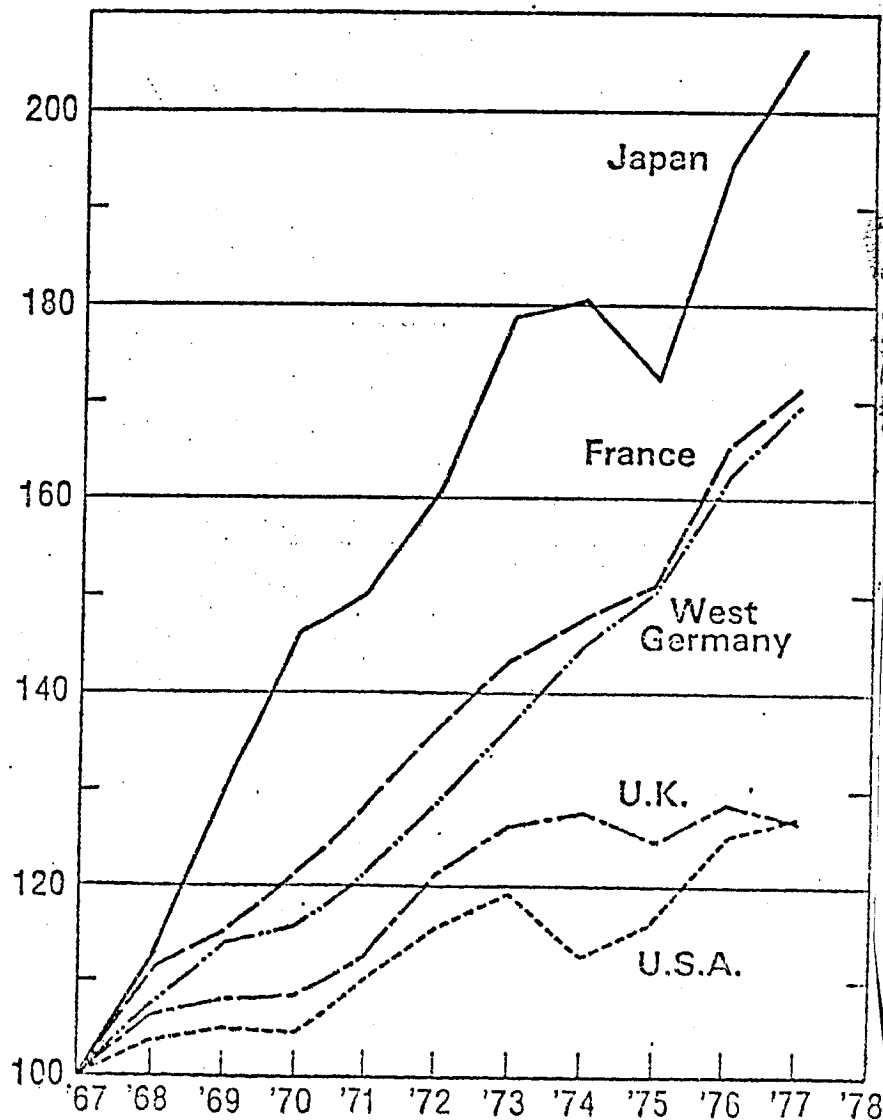
It should come as no surprise that, in the face of an increasing accumulation of physical capital and semiskilled labor in the developing countries, they have become increasingly competitive in those low technology commodities traditionally representing U.S. comparative advantage--even in the U.S. domestic market. However, major inroads have been made into U.S. domestic and export markets in other industries where economics of scale in production are critical, and/or where there are only small, inefficient producers or major producers serving only the U.S. market.³ It has been asserted that to be competitive internationally a firm or technology must first be competitive in its own domestic market.⁴ Because increasing competition is being felt by U.S. producers of high technology in their own home market, it is useful to determine what factors, both at home and abroad, have contributed to this state of affairs.

Foreign technology may be deemed as competitive in the U.S. market if it is viewed by the purchaser as comparable in quality, price, performance and overall delivery and servicing requirements and/or provisions. Primary emphasis is placed on the cost effectiveness of the purchase based on and compared to technological alternatives offered by competitors. Given this, two related facts are especially pertinent: one, that innovation leading to increased productivity (and therefore decreased cost per unit of manufactured output) is a primary determinant of competitiveness; and two, that the U.S. rate of productivity growth is the lowest of all the developed countries except the U.K.⁵ (See Table I below.) Germany, France, and Japan all are outpacing the U.S. in productivity growth, and the pressure felt by U.S. high technology producers in the domestic market is exerted principally from Japan,

and to some extent, from Germany. Therefore, while the body of this discussion will introduce data from all four major competitors (Japan, Germany, France, and the U.K.), the primary emphasis will be placed on Japan, and secondary emphasis will be on Germany. Data for other countries will be introduced only to provide examples of particularly important factors contributing to the competitiveness of their high technology exports.

TABLE I
International Indices of Labor Productivity

Output per Hour of
Manufacturing Workers,
Normalized to 1967



Source: "Productivity," U.S. Congress, House, Joint Economic Committee, Washington, D.C., U.S. Government Printing Office, 1979. Hearings Before the Committee June 5, 1979, p. 3.

II. GOVERNMENT POLICIES AND PROGRAMS

Several types of government policies and programs abroad both actively and passively support economic expansion and productivity in general, and the development of high technology and innovation specifically. Some are "global" in that they are not focused on specific industries or technologies, and their impact on the enhancement of innovation, productivity, and competitiveness is intended to strengthen general national competitiveness and facilitate a more productive economy. Selective technological innovation programs, on the other hand, are designed to encourage specific industries or technologies, and usually represent a direct government intrusion into the market place.⁶

A. GLOBAL PROGRAMS AND POLICY INSTRUMENTS ENCOURAGING INDUSTRY--AND NATION WIDE INNOVATION, PRODUCTIVITY AND COMPETITIVENESS.

1. Industrial Restructuring Plans and "Administrative Guidance." Given the continuously intensifying level of international competition, major foreign industrial programs generally have moved away from relatively short term, defensive industrial policies, to longer term well coordinated offensive industrial policies. In Japan, for example, the national economy has not been left to the free play of market forces. At the end of World War II, it was perceived that a well planned and coordinated economic policy was necessary to put the country back on its feet by assuring that scarce resources were allocated to those sectors of the economy which could produce the best results. Accordingly, the Japanese government undertook to identify objectives and priorities for the Japanese economy. The government of Japan is characterized as being a "well structured planning organization" with effective coordination between legislative and executive branches, thereby assuring compatibility of goals and approaches.⁷

Industrial policy is tied closely to national development policy. While there is only a limited legal basis for the government's involvement in the private sector, the "administrative guidance" that takes place is based on a history of close communication between the Japanese business community and the government that began with the Meiji Restoration (1868-1912).⁸ Furthermore, the acceptance of government goals and priorities by the business community is based on two factors:

- "A reluctance on the part of both business and government to unilaterally adopt policies or undertake major moves in the high priority sectors of the economy without consulting each other;
- a propensity, which all Japanese share, for a consensual approach to harmonizing differences that may exist within as well as between each group."

The relationship is also based upon a spirit of confidence and trust and in a conviction that such a relationship is the most efficient way to achieve a high rate of growth for both the business community specifically and the country in general. It is interesting to note that, possibly as a result of the tendency to mediate disputes and avoid confrontations, Japan has roughly 1/30th the number of lawyers as does the U.S.,¹⁰ with roughly half the total population. This also reflects a predominantly leadership-oriented, rather than regulatory, government approach toward business.

Even in the face of the above, it would not seem reasonable to term the Japanese economy as "planned" in the communist or socialist sense, even though the contact and coordination between government and business is close. Some feel that it is, in fact, difficult if not impossible to make a clear distinction between government and business. The terms "mixed economy," "consent economy" and "sponsored capitalism" have been used to describe the system of government guidance to private sector activity.¹¹ It has been pointed out that industry does not always follow government

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direction, and occasionally works without significant government assistance on major efforts. One time, for example, the government felt that Japan could not compete in the automobile industry since the market was dominated by the U.S. Even though they were deprived of preferential government financial treatment, the industry proved innovative and became successful.¹² The point is that:

"The administrative bureaucracy exerts a powerful influence on the course and shape of Japanese development. It promotes, projects, controls, regulates, and often manages economic activity. In doing so, government consults frequently with the industry and firms involved, both before and during the implementation of measures and programs adopted."¹³

Within this general approach, national economic plans are developed under the direction of the Prime Minister and prepared by the Economic Planning Agency (EPA) assisted by representatives from business, and to a lesser degree, universities, research institutes, and the press. Targeted industries are selected by the EPA, broad objectives for the economy are set and forecasts of production and investment levels are made to provide industry with a plan of the forecast direction of the economy. Industrial planning is then carried out by the Ministry of International Trade and Industry (MITI) in close collaboration with businessmen. Specific industry-by-industry goals are set within the framework of the EPA plan. These plans and goals are set on the basis of a number of factors, including everything from foreign policy and foreign aid objectives to projected make up of the Japanese labor pool, and indepth analyses of technologies and markets. Once such "plans" are set, whether by negotiation, consensus, or threat, (depending on your

perspective) a direct effort is made by the government to assure that its objectives are met. Fiscal, financial, material, and other incentives are used.

2. Special Tax and Depreciation Measures. Tax and depreciation incentives for investment in productivity, innovation, and R&D are extremely important and are widely used in Japan and Europe. In Japan, for example, there were special tax exemptions and accelerated depreciation rates were granted to export-oriented industries in the 1950's and 1960's (such as textiles, steel, chemicals, and consumer electronics) to encourage the buildup of foreign exchange reserves and to finance imports of technology and equipment. Currently, Japan offers special tax treatment for R&D expenses in industry, and special tax treatment for corporate incomes derived from exporting technology. Both Germany and Japan offer special tax treatment of grants from private sources to promote science and technology.¹⁴

In Japan, France, Germany, and the U.K., further tax incentives are offered to companies complying with government industrial policy. Qualifying plant and equipment are eligible for up to 100% first year depreciation allowances in the U.K. (50% in France), and in some cases organizations engaged in scientific research are exempt from corporate taxes. Tax deductions for investment in R&D are nearly universal, and in Japan there is even special tax treatment of inventor's costs and income. Germany also offers fiscal incentives for extra-professional scientific work.

3. Preferential Financing Provisions. In Japan, the New Technology Development Corporation (a government corporation) gives special financial assistance to firms commercializing research results. If the venture is not successful, the loan need not be repaid. In addition, the Corporation undertakes to introduce government and university developed research to companies for commercialization under the above terms. In general,

preferential loans are offered by banks to high priority industries and technologies in accordance with the national and economic development plans developed by the EPA and MITI. Since the Japanese government owns the banks, this constitutes a subsidy for high technology high growth, high productivity industries. Because the average net worth of Japanese corporations is only about 20%, they are highly leveraged by such bank loans. This high debt/equity ratio facilitates Japanese government influence in the allocation of financial resources and enhances control over Japanese industrial development through government owned banks.

Direct financial assistance also is offered in Japan through a number of MITI, Japan Development Bank, Small Business Finance Corporation, Ministerial, and other agencies' activities which subsidize R&D for "important technology," technological improvement, and applied technologies of various types. Similarly in France, Germany, and the U.K., various direct financial assistance packages are offered. Interest free forgivable loans (such as under the First Innovation Program in Germany), grants (e.g., Financial Support for R&D in Industry Program, in U.K.), equity sharing (in France), and other subsidies are granted to targeted industries. In many cases, small and medium industry is favored by special programs which subsidize salary and other costs for R&D staff, internal and external research projects, modernization, management improvement, energy conservation, joint ventures, structural improvement, etc.¹⁵

Other specific forms of direct financial assistance of interest include the European Recovery Program Special Fund, comprising DM 500

million (1978) in loans to targeted small and medium sized firms in Germany, and the R&D Industry Program in the U.K., which supports small firms, research associations, and university R&D with \$9.5 million/year. The U.K. National Research and Development Corporation supports joint ventures with industry. In France, the government offers grants for industrial modernization and funding for new enterprises.¹⁶

In many cases the above direct financial assistance, in addition to loan guarantees, insurance assistance, government certification, interest subsidies, etc. are offered in response to a failure of liberal tax incentives to provide the basis for internal company venture capital formation. Because of cultural and/or structural impediments in Japan, Germany, and France, the U.K. is the only one of the four countries with any significant number of private venture capital companies. In any event, such direct subsidization is granted on the premise that selective public investment in private industry will be repaid in the form of national and sectorial competitiveness, productivity, and efficiency.

4. Aid to Cooperative Research And The Use Of Government R&D Facilities By And For Industry. Complex research projects involving the resources of diverse technical fields, industries, universities and government facilities are more and more often promoted and coordinated by governments. Most foreign cooperative R&D programs support both the development of technology for a specific targeted industry, and also the development of technologies to be used by a number of firms or industries. They also often support specific projects at individual firms in addition to industry

wide work at research institutions. Other than the U.S., all of the world's industrialized countries have at least one formal mechanism for supporting cooperative R&D between government, industry, and academia, and such tripartite arrangements clearly spearhead efforts at innovation and productivity improvement. The role of the government is of direction, leadership, and coordination of the national effort, and funding. The role of industry is not only to provide funding, but also to utilize the research results in the proprietary development of its products. The role of the universities is to carry out the research and to assist in the implementation of the results. The Germans and the Japanese have decided that, especially in new fields emerging from the confluence of many technologies, the most effective way in which to utilize diverse and decentralized research resources is on a cooperative, cost-sharing basis. Many experts agree that such cooperation is a necessary prerequisite to a dynamic industrial policy, and that it is effective in enhancing national and sectoral innovation and productivity and, therefore, competitiveness.

Examples of such cooperative R&D programs abound. In Japan, the Synthetic R&D Projects program provides financial aid to industry to promote joint R&D between government research institutes, industries, and universities. This is done through the Science and Technology Agency, the Agency of Industrial Science and Technology and numerous ministerial and other research corporations oriented toward specific technologies. In Germany, 80 research associations in 31 branches in industry used DM 67 million in fiscal year 1979 in joint R&D. In England there are more than 50 industrial research associations involved in cooperative R&D with industry.

In France, efforts are being made to push ahead in the areas of information processing, microelectronics, consumer electronics, and automation through strong government-industry cooperation in 14 national projects under the Ministry of Research and Technology.¹⁷

Government R&D facilities in many countries are made available to perform research for individual firms on a fee basis. The West German Fraunhofer Society for the Promotion of Applied Research, the U.K. Atomic Energy Harwell Research Establishment, France's Delegation General a La Recherch Scientifique et Technique, and Japan's Agency of Industrial Science and Technology (among at least 21 others in Japan) are all available for this purpose. Several governments give grants to small, innovative firms which may be used to purchase research services from such facilities.¹⁸

It is worthy of note that, with the blessings of their governments, European corporations are entering into complex joint ventures to acquire technology from the U.S. and Japan.¹⁹ Having put together a four-way venture in telecommunications, the chief executive of AEG-Telefunken recently said that this was done primarily because, without such co-operation, AEG could not even reach the break-even point on many products.

5. Technology Information And Transfer Service. The promotion of cooperative research is also achieved through non-traditional modes of interaction and the exchange of information. Japan's New Technology Development Interaction Program and Synthetic R&D Projects, and Germany's Advisory Committee System interconnecting industries and R&D institute boards, and the Max Planck Gasellschaft are all oriented toward specifically enhancing information exchange between industry and universities.

Specialized Information Centers in key scientific and technological areas in all four countries, but Japan, especially, have been characterized as excellent environments for information gathering.²⁰ NIST (National Circulation of S&T Information), the Japan Patent Information Center, Oceanic Science and Technology Center, and at least seven other agencies are designed specifically to transfer technical information and expertise. In addition, there are numerous organizations which do so as an important ancillary service coincidental to their primary R&D activity.

Information gathering in Japan may be viewed as something of an obsession. The Japanese continually send groups all over the world to visit countries and find out what is happening in economics, technology, and other areas. Japan has about 45 English speaking correspondents in Washington, D.C., alone, while there are "perhaps 3"²¹ U.S. correspondents in Japan who can speak Japanese. This is indicative of a highly developed consciousness of the necessity to go to where the information is and procure it in the most efficient manner.

6. Regulatory Provisions and Enforcement. Government regulations of various types have a significant influence on innovation and productivity, and therefore on competitiveness. In Japan, enforcement of anti-pollution and anti-monopoly regulations historically has been lax. Currently, however, there are more than 14 anti-pollution laws in addition to the 1967 Anti-Pollution Measures Basic Law which are being more stringently enforced as a result of a rapidly deteriorating environmental situation in the 1960's and 1970's. Since 1975 many industries have been required to spend as much as 20-30% of their investment capital on pollution control and abatement

equipment.²² At the same time, however, "the Japanese government sometimes encourages the mergers and technical cooperation among competing companies to strengthen their economic base."²³ Frequently, in times of economic recession, the government has allowed industries to engage in price fixing. A similar situation exists in Germany. There is a general attitude that environmental restrictions will be enforced to the extent practical, ensuring continued gains in productivity, but not to preserve what might be regarded as inappropriate or unreasonable standards. Government seeks industry participation in the formulation of regulations; and there is some feeling that regulating agencies should determine the "ends" to be achieved, while allowing industry to determine the necessary "means" to achieve those ends.

7. Employment Adjustment Programs. The impact of technology on employment promises to be considerable in the future. Bearing in mind the constant search for labor saving devices, the use of robots, etc., governments have initiated numerous programs to insure continuing labor-management harmony, reduce labor resistance to displacement by technology introduced to production lines (and elsewhere), and to encourage the conversion of labor from lower to higher technology occupations. Japan and Germany both offer free job placement and advice, pay for advanced training and re-training, and maintain formal systems to encourage employment stabilization.²⁴ The Japanese rely heavily on lifetime employment systems in larger corporations to maintain employment, re-train displaced employees and send them to other operational departments in the company. This is done with the assistance of government loans, grants or other subsidy support.

8. Export Promotion. Because of its near total dependence on imports for energy, raw material, and other resources, Japan has developed policies and programs to promote the export of manufactured goods. Government financial incentives to export high technology specifically include special loans to cover export insurance and risks occurring as a result of foreign exchange fluctuations. There are special tax incentives taking the form of deductions on income from technology exports. For example, certain exporters can deduct a part of export income as a business cost if it is saved as a reserve for developing overseas markets. There is a proportionately larger depreciation allowance for capital equipment used to manufacture exports, and various reserves to cover overseas investment risks. Additionally, marketing assistance is provided by JETRO (Japanese External Trade Organization--a government agency) through information services, and a number of sophisticated general purpose trading companies provide a "one stop" source for the full range of services which are required to sell a wide variety of products abroad. These trading companies are particularly important vehicles for information gathering and dissemination because they have offices around the world. They do from \$30 billion to \$60 billion worth of business per year and provide valuable services, especially to small and medium sized companies that do not have the resources to otherwise compete internationally.

The governments of Japan, the U.K., and France all offer substantially more official and more complete export financing packages than does the U.S. Japan, Western Europe, and the U.S. have all agreed to maintain currently available terms for export financing at their current levels until further notice, leaving the U.S. at a continuing cooperative disadvantage.²⁵

All of the above "global" policies and programs point to a concentrated effort to encourage industrial development as an integral and logical component of a larger, longer range national economic development scheme. Many have pointed out that such long range planning and government support for industrial or technological development enables industry to concentrate on long range considerations such as market share lending to long term profits, and that this allows them to be less concerned with short term profits, like their U.S. competitors.²⁶ Others point out that such planning and coordination between government and business would never be possible in the U.S., given the traditional adversary posture between the U.S. government and the private sector.²⁷ Still others state that, even given a relaxation of that adversary posture, it is doubtful if the U.S. possesses adequate talent to engage in such exercises as national economic planning.²⁸ Such long range planning and cooperation between government and industry as manifested in the policies and programs described above have greatly enhanced the competitive stature of Japanese (and other countries') industries in the U.S. high technology market.

B. SPECIFIC PROGRAMS TO ENHANCE INNOVATION, PRODUCTIVITY, AND COMPETITIVENESS IN SELECTED INDUSTRIES AND TECHNOLOGIES

There are several notably successful programs specifically devoted to promoting the development of selected industries and technologies in a number of countries, especially Germany and Japan. While many governments, including the U.S., offer support of various types to industries and sectors in structural decline, these generally are not in high technology areas, but rather in sectors such as shoes, textiles, clothing, ship building, steel, foundries, etc. Specific defensive measures in support of such industries world wide have included everything from nationalization, subsidization and reorganization to special tax considerations and trade protection.

Of more direct interest are measures which promote high technology, high growth industries. It has been suggested that one reason for the disparity in growth and productivity rates between U.S. and Japanese industry is because the U.S. generally only subsidizes low productivity industry, while Japan generally only subsidizes high productivity industry.²⁹ It is worth noting that both Japan and Germany make an effort to develop industries which utilize technologies not easily adopted by the developing countries.³⁰

In Japan and Western European countries there are several programs designed specifically to support high priority, high growth industries. For example, the following are estimates of direct Japanese government assistance to industries for R&D in 1977:³¹

- Chemicals ¥ 1.1 billion
- Ceramics ¥ .4 billion
- Iron & steel ¥ .6 billion
- Nonferrous ¥ .4 billion
- Machinery ¥ 3.5 billion
- Electrical machinery ¥ 7.5 billion (includes computers)
- Transportation (non-auto) ¥ 12.2 billion
- Special corporations for promoting R&D also contributed ¥ 8.7 billion

During the 1970's the Japanese government (MITI) committed \$350 million to a research project for very large scale integrated circuits, and it is estimated that during the same period companies spent 20 times more on the same "project."³² Companies obtained funds for the work through banks offering concessionary loans. In 1981 MITI persuaded 14 Japanese companies to join a research

association in the field of genetic engineering to conduct an estimated \$150 million in government sponsored research.³³ Government spending in the area of energy research (conservation, coal liquifaction and gas-sification, alternative energy) is roughly \$2.5 billion per year. MITI has pledged \$450 million to a 10 year R&D project in ceramics and new plastics.³⁴

All of the above are in addition to the previously described "global" programs and policies.

The Japanese government, in its Industrial Policy Vision of the 1980's, identifies the following targeted technologies and industries:

- optical fibers
- ceramic materials
- amorphous materials
- high efficiency resins
- coal liquefaction
- coal gasification
- nuclear power
- solar energy
- deep geothermal generation
- ultra high speed computer
- space development
- ocean development
- specialized aircraft³⁵

Development of these areas will be promoted through direct government R&D funding, made more efficient through mechanisms promoting cooperative/joint R&D, and the availability of government R&D facilities, and made cheaper

and more attractive through the various tax and other policies encouraging their implementation.

Likewise, West Germany has several programs designed to promote the development of specific technologies. Among them:

- electronic components
- communications and information techniques
- physical technologies under threshold conditions
- optics and measuring techniques
- control engineering
- power engineering
- materials technology
- processing engineering construction techniques and manufacturing techniques
- mining processes
- innovation in small businesses
- nuclear technology
- civil aircraft development
- data processing³⁶

The German government will spend \$135 million over the next three years to help companies apply microelectronics to new products.³⁷ Utilizing the tripartite action of government, industry, and the universities, the German government has funded a massive program of manufacturing technology R&D designed to have the greatest impact on industrial manufacturing productivity. The greatest share of the research, development, and the implementation is toward "the applications of the computer to on-line optimization and automation of both the soft and hard components of the total manufacturing system"--³⁸ computer integrated manufacturing. This represents a concrete manifestation of the cooperative/joint research mechanism described above under global

programs, and its efficiency is enhanced by the availability of facilities from AIF (Federation of Industrial Research Associations--80 such associations in 31 branches of industry) and FLG (Fraunhofer Society for the Advancement of Applied Research).

In the U.K., several programs directly finance industrial high technology development. For example:

- Computer Merger Scheme, Development Contracts Scheme, and Advanced Computer Technology Project have provided \$2 million in contracts to computer R&D firms, \$36 million in grants in high priority R&D, and \$1.3 million in annual investment in advanced computer R&D.
- Department of Industry--several schemes in energy conservation, product and process development, and micro-processor applications.
- R&D Requirements Boards support chemicals and minerals; engineering materials; mechanical engineering and machine tools; computers, systems, and electronics; space technology; and civil aircraft technology R&D.
- High Technology Department of Industry Sectoral Industry Schemes in electronic components, instrumentation and automation, and microelectronics.

Other government programs directed \$13 million into R&D at three leading electronics firms and \$24 million into telecommunications in 1979.

In France, efforts are being made to transform the nation's electronics industry into a single, integrated whole by investing in 14 national projects in areas of speech synthesis and recognition modules, computer aided design and manufacturing systems, mini- and micro-computers, and a very large main-frame computer model.

These efforts by the Japanese, German, French and U.K. governments represent a direct intrusion into the market place and constitute direct subsidies of technological development. In looking at the technologies selected for support, it seems that targets are chosen on the basis of their higher chances for competitive success in the market place.

III. OTHER FACTORS ENCOURAGING INNOVATION, PRODUCTIVITY, AND COMPETITIVENESS IN HIGH TECHNOLOGY INDUSTRIES

In addition to the formal policies and programs described above there are several other factors contributing to the rapid growth and productivity, and therefore competitiveness, of foreign high technology industry. While many of these factors are directly related to, or occur as a result of, such policy/program incentives, some appear to have been preexisting and have actually encouraged such policies/programs.

A. CAPITAL INVESTMENTS

Many industries in Japan maintain what is called a 10 year "scrap and rebuild plan" to remain competitive in international markets.³⁹ This reflects the availability of large amounts of capital and provisions for accelerated depreciation offered to high priority, high growth, high productivity industries. Such industries are, as previously mentioned, heavily debt financed, and as the Japanese government owns the Bank of Japan and the Bank of Japan owns the commercial banks, preferential financing (and perhaps financing period) is available only to targeted industries. Furthermore, the Japanese government backstops the banks, thus giving them greater security in undertaking risky investments and loans.

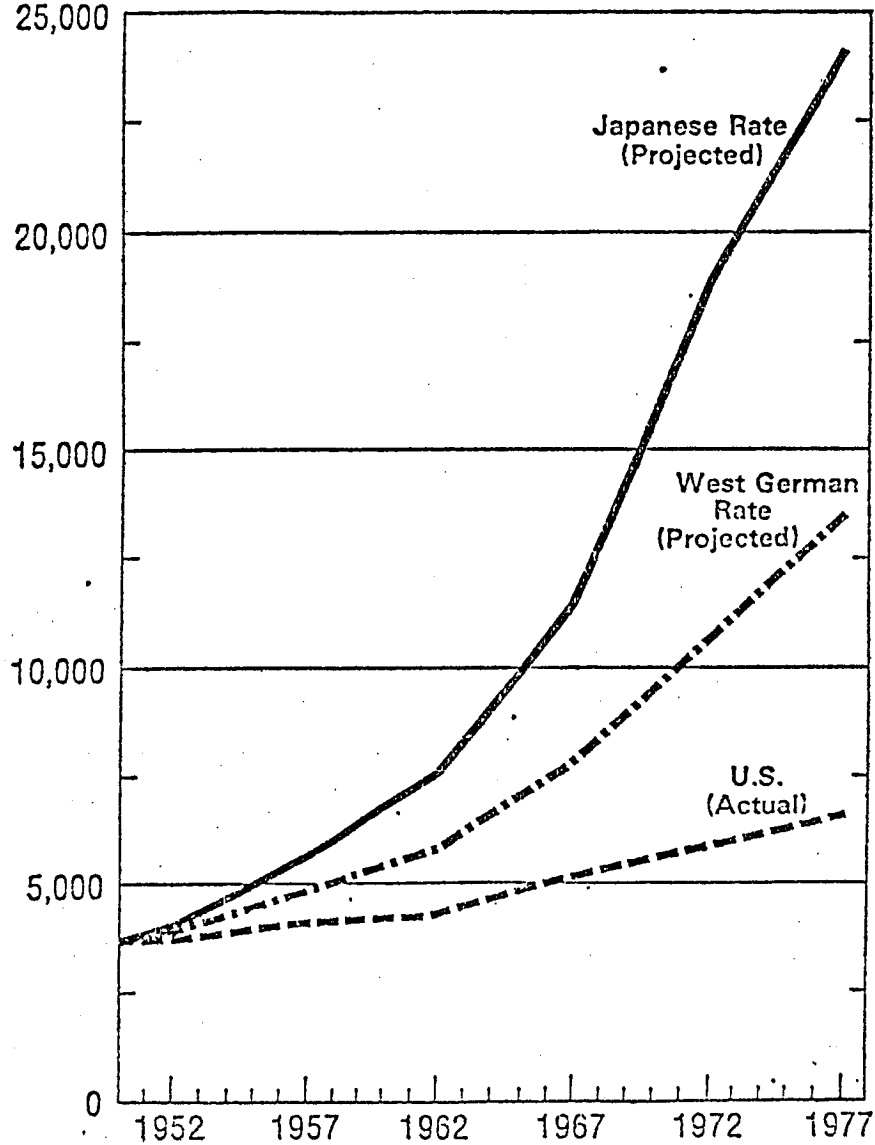
The large amounts of capital needed for these investments are made available because of the 20 plus percent of disposal income savings rate of the Japanese worker. (See Table II below.) This rate of

TABLE II

Real Per Capita Disposable Personal Income

1978 Dollars

25,000



Source: "Productivity," U.S. Congress, House, Joint Economic Committee, Washington, D.C., U.S. Government Printing Office, 1979. Hearings Before the Committee June 5, 1979, p. 4.

savings helped to maintain an annual level of investment in plant and equipment of 29% of real output between 1962 and 1972.⁴⁰ In 1978, Japan allocated 10.9% of GNP to gross fixed capital formation in machinery and equipment (the U.S. allocated 7.3 %, Germany 8.9%, France 9.1% and U.K. 9.2% in the same year).⁴¹

The capital available per worker in Japan increased by 10.1% per year between 1963 and 1975 (compared to 1.7% for the U.S.), while the Japanese share of world capital doubled from 7 to 15% (the U.S. share declined from 42% to 33%) in the same period.⁴² Foreign high technology competition may well continue and in fact increase in the 1980's because the U.S. continues to lag behind Japan and Western Europe in net real investment growth, and is, in fact, maintaining the lowest rate of productivity growth of all our major competitors except the U.K.

B. TECHNOLOGICAL INNOVATION - R&D

The official stance at the U.S. Office of the Japanese Productivity Center is that the importance of technological breakthroughs in increasing productivity cannot be overemphasized.⁴³ Studies by experts in the past tend to substantiate this stance, as indicated by the following table:

TABLE III
CONTRIBUTION TO PRODUCTIVITY INCREASES
[In percent]

Studies	Labor	Capital	Technology
Denison.	18	20	62
Kendrick	10	18	72
Christenson, Cummings, and Jorgenson	14	42	44
Average	14	27	59

Source: "Productivity," U.S. Congress, House, Joint Economic Committee, Washington, D.C., U.S. Government Printing Office, 1979. Hearings Before the Committee June 5, 1979, p. 16.

On average, technology is viewed as the leading contributor to productivity improvement. And yet, according to the OECD, U.S. Government spending on civilian industrial growth in total (not only R&D) in 1976 was the lowest of all the developed countries both in absolute terms and as a proportion of total government spending.⁴⁴ Japanese investment in industrial R&D consistently has outstripped U.S. investment over the last decade. Japanese total R&D investment reached a level of 2.5% of GNP in 1981 compared to about 2% for the U.S.⁴⁵ It is important to note that the U.S. figure also includes space exploration and weapons production, whereas nearly all of the Japanese figure went to R&D for commercial products and processes. In addition, U.S. industry funds only 44% of total R&D compared to Japan's industry rate of 71%.⁴⁶ Perhaps even more important is a comparison of the downward trend in percentage of GNP devoted to total R&D in the U.S. and the upward trend in Japan, Germany, France, etc.

Japan has placed heavy emphasis on the development of high speed and large-scale computers, peripheral equipment, medical electronics, and communications equipment R&D. Wherever a serious attempt is made to develop practical industrial applications of high technology to increase productivity, industrial efforts are met with enthusiastic encouragement by the government, as evidenced by the various general and specific policies and programs described above.

In addition to conducting basic and innovative R&D at home, the Japanese are known as masters at improving on other nation's products and processes. Over the past 30 years, Japanese firms have spent more than \$30 billion in fees and royalties for foreign technology.⁴⁷ Past successes are a matter of record, but the tendency for exploiting U.S. technological achievements continues and the Japanese are known as being among the most assiduous pursuers of scientific, technological, and industrial information

in the U.S.⁴⁸ Japanese-U.S. technological cooperation is likely to be weakened by the recent Silicon Valley industrial espionage scandal involving employees of Japan's Hitachi, Nissei, and Mitsubishi. Although there was an outcry deploring these companies' "wretched ways of collecting foreign knowhow" in the Japanese press, feelings in the U.S. are plain.⁴⁹

Incentives exist, then, not only to promote the conduct of R&D in Japan, but also to promote its rapid commercialization, providing the activities relate to a high growth, priority industry or technology. Given Japan's emphasis on developing a high technology, knowledge intensive society, nearly any high technology effort contributing to increased innovation and productivity and to lower costs for industrial output would appear to qualify for preferential treatment.

In Germany, and elsewhere in Western Europe, the trend also is toward cooperative R&D between government, industry, and universities, and targeting specific research areas for government research funding--such as computer assisted machining and computer integrated manufacturing. In Fiscal Year 1979, the German government contributed DM 67 million to such cooperative research through 80 research associations in 31 branches of industry. In the U.K. about 50 industrial research associates participate with the Government Science Research Council attempts to direct students toward industry and to administer priority funding in areas of industrial relevance. The French also aid government, industry and university cooperation through technical research contracts and collective research centers.⁵⁰

C. RISE IN THE EDUCATIONAL LEVEL OF THE WORK FORCE

The Director of MITI, in a recent interview, said that Japan was "really trying to create knowledge intensive industries. All industries have to become

smarter both in the way they make things and in the amount of knowledge the products themselves contain."⁵¹ To achieve these goals, and to improve worker skills, Japanese companies generally spend more money per employee than their U.S. counterparts in training workers.⁵² While it is true that 48% of U.S. high school graduates attend college, as opposed to only 42% for the Japanese, Japanese high school graduates generally are better grounded in science and mathematics than their U.S. counterparts, and they do considerably better in international comparative tests, especially in science. Also, a much higher percentage of Japanese students are in engineering (20% undergraduate and 40% post graduate).⁵³ With only half the population of the U.S., Japan is now graduating about 20,000 more engineers per year than the U.S. Partly as a result of a much greater effort to meet manpower needs through government-business cooperation, superior scientific, mathematics, and engineering talent is being developed in Japan even though Japan has fewer teachers per number of students than the U.S.⁵⁴

D. LABOR-MANAGEMENT RELATIONS

In 1977, Japanese corporations were losing about 1.5 million man days to strikes per year compared to the figure of 35 million days in the U.S.⁵⁵ In management as well as on the shop floor in Japan, participatory and consensus-based decision making is prevalent. Labor management councils, quality control circles, and various other worker-oriented voluntary programs have contributed greatly to the workers' sense of security,⁵⁶ to increased productivity,⁵⁷ cost effectiveness, and quality control in production, and to a dampening of labor agitation.⁵⁸

The Japanese, and to some extent German, propensity to avoid confrontation has contributed to harmonious worker-management relations. While in the U.S., the U.K. and elsewhere in varying degrees, labor has agitated against

the introduction of labor replacement technology, the Japanese have kept unemployment to the 2-3% level through corporate life-time employment systems and government sponsored retraining programs. Where government sponsored programs do not pay for such training, corporations do. Even in times of economic recession, Japanese corporations do not lay off employees unless bankruptcy is imminent. If employees are not senior enough to be retired with special bonuses, they generally are transferred to other companies when openings occur. Because of these policies, Japanese workers see the commitment made to them by the corporation, and in time realize that their own prosperity is directly linked to that of the corporation. Workers know that, by and large, if they are displaced by a technological improvement which increases productivity on the production line and this lowers costs, that this increases profits which go into other lines of production, and in turn enables the worker to be retrained and reemployed. Given a high level of labor stability and security, an equally high degree of mutually directed confidence exists which allows for the rapid introduction of innovative, labor saving technology which increases productivity, and therefore competitiveness.

IV. CONCLUSIONS AND RECOMMENDATIONS

While all four of the U.S.'s major national competitors in high technology have engaged in an effort to design and implement a national industrial policy, some have been significantly more successful than others. It is therefore of little value to note the Japanese success and suggest that their planning model is worth following elsewhere, given the considerable difference between the U.S., Japan, and other national environments.

It may, on the other hand, be useful to examine some of the reasons why policy, per se, was successful in Japan, and not particularly successful in, say, the U.K., and see if there may be some lessons to be learned.

Often, it is pointed out that the Japanese political and social system is dominated by a cultural tradition steeped in highly formalized systems of etiquette, loyalty, and duty and dominated by a strictly structured hierarchy of power and roles. A spirit of cooperation and an aversion to confrontation, it is said, makes the consensual approach to decision making possible and practical in Japan, and when combined with a pervasive patriotism provides for easier direction of group efforts such as industrial plans. The above could be offered as at least partial explanation for the Japanese success, but it offers no hint as to the cause of the U.K. failure, for certainly the British can be attributed with no less of a traditional love of God, King, country, and "form," nor can they be described as thriving on confrontation, although British labor militancy certainly has had a negative effect.

The secret, at the risk of being simplistic, rests in something deeper, and more closely tied to what may be described as basic human nature, not culturally defined or determined. The basic issue is that of reacting to a perceived threat and maintaining one's security. Since perception defines reality for the individual, it is the key word. The Japanese

perceive, and truly so, that they are an island nation with few natural resources. Japan depends on overseas supplies for 90% of her energy and raw materials. She was left at the end of World War II with a destroyed economy, the Emperor humiliated, and a crushed national pride. In a way, she had been overcome, more than by anything else in the final analysis, by technology. With little arable land and a large population expanded by returning soldiers and colonists, Japan had to develop an internationally competitive industrial sector that could both meet domestic demand and also export to finance required imports of food, energy, and raw materials. It was perceived as a question of "adapt or die" at the time, and continues to be.⁵⁹ It is significant to note that the perception has not changed at all from that time to the present. Japan continues to be highly reliant on imports of energy and raw materials, continues to have little arable land, and continues to have a large population. She also continues to react to these threats and to strive to insure her security. Japanese are united in facing international competition because they know that if they do not, they will be left behind. Their exports will no longer be able to finance imports necessary, literally, for survival. The Japanese view survival as the basic issue.

The U.K., on the other hand, also was left with an economy in ruins. Its political and social systems were, however, reinforced. The British had, after all, won the war. There was, therefore, less reason to restructure or change. Because they were "successful," they were hindered from making changes in thinking. Given the courage of their convictions, there was little reason to continue in other than traditional ways, which they largely did.

The radicalism in the restructuring of the Japanese economy reflected the high degree to which the Japanese felt threatened. They also had the benefit of millions of dollars in U.S. aid, advice

and other assistance. The Japanese Productivity Center, for example, was founded by the U.S. State Department as part of the post war reconstruction assistance program and, until 1962, received about \$1 million per year in assistance. Put to good use, this assistance provided a means for Japanese executives and engineers to gain a window on the state of the art in U.S. management and production processes, and to better understand trends in technology, industry, and management. A willingness to restructure--to change--combined with an understanding of current and future technology trends certainly facilitated the foundation of successful policy. The Japanese understanding of such trends and the adequacy of their projections are reflected in their current success. An accurate perception of economic threat and a willingness to change to meet it headlong, has played a large role in this success.

Japanese decisions in the planning process have been made on the basis of sound business and management judgment, basically unhindered by popular political interference or adherence to ideals of free enterprise or democracy. Growth, productivity, and foreign exchange earnings have been the targets.

The U.S. posture in general seems to be that, given a heritage of vast resources and an innate quality known as "Yankee ingenuity," the U.S. can and will rise to any occasion. The problem is that the U.S. depends on exports less than any other developed nation for its economic well being. It has taken years to convince the American people that "exports mean jobs," and that it takes exports to finance imports. The characteristic response of industry and government to foreign competition is to cry "foul," and to decry "unfair" Japanese management and government practices and to threaten the initiation of protectionist measures, rather than to learn from the competition, and initiate innovative practices to improve productivity and competitiveness.

In addition to the U.S. failure to respond effectively to the changing international trade environment, there has been little U.S. appreciation for the real strength of the Japanese threat because it was asserted that the Japanese cannot create, only copy. Or that Japan can compete in U.S. markets only by dumping.

Given an adequate understanding of the true nature of the threat, the following recommendations would seem to be in order:

- Put industrial productivity on the same footing as defense and space as a matter of national security.
- Identify specific industries as preferential by virtue of their contribution to high technology, productivity, innovation, foreign exchange earnings, or other desirable qualities, and offer every practical incentive to promote their development and advancement.
- Do not subsidize or otherwise support industries in structural decline at the expense of industry on the ascendancy except in cases of absolute necessity as dictated by national security interests.
- Recognize the growing competitive advantage of the developing countries in labor intensive, low productivity, low technology industry, and divert wasted capital in the U.S. away from such industries which will not be competitive without protectionist measures that are largely counterproductive.
- Initiate a meaningful job retraining program to assure the replacement of workers displaced by technology.
- Initiate a public awareness program to prepare the U.S. public for a high technology future and to better acquaint them with a realistic role for the U.S. in an international economy undergoing radical change.
- Require scientific and technological curricula for graduation from U.S. secondary and high schools.

As nations vie in an ever more highly competitive mode for a more secure portion of the high technology market, productivity and the ability to produce high quality goods at lower prices will be increasingly important. Specifically, the U.S. will be required to be innovative in formulating its response to foreign competition strengthened by close cooperation between governments and industry. It is entirely possible that new models for such cooperation in America may hold the key to maintaining or increasing U.S. comparative advantage.

FOOTNOTES

1. U.S. Congress, House, Joint Economic Committee, U.S. Export Competitiveness. Washington, D.C.: U.S. Government Printing Office, 1980. Hearings before the Committee, July 29, 1980, p. 25. (Hereinafter referred to as Export Competitiveness.)
2. U.S. Congress, House, Joint Economic Committee, Productivity, Washington, D.C.: U.S. Government Printing Office, 1979. Hearings before the Committee, June 5, 1979, p. 7. (Hereinafter referred to as Productivity.)
3. Op. Cit., Export Competitiveness, p. 54.
4. Ibid., p. 47.
5. Op. cit., Productivity, p. 3, also, Bunten-Mines, et al., "Cooperative R&D Programs to Stimulate Industrial Innovation in Selected Countries," Office of Cooperative Generic Technology, U.S. Department of Commerce, June, 1980, p. 3. (Hereinafter referred to as "Cooperative R&D Programs.")
6. Information in this section is taken largely from:
 - "Cooperative R&D Programs"
 - Productivity
 - U.S. Department of Commerce, Japan. The Government-Business Relationship, Washington, D.C.: U.S. Government Printing Office, May, 1972. (Hereinafter referred to as Japan.)
7. Op. cit., Productivity, p. 7.
8. Op. cit., Japan, p. 10.
9. Ibid., p. 10.
10. Vogel, Ezra F., "Can the Japanese Keep It Up?", The Innisbrook Papers, p. 30-32.
11. Op. cit., Japan, p. 13.
12. Donlan, Thomas G., "Yen For Productivity," Barrons, August 2, 1982, p. 28-29.
13. Op. cit., Japan, p. 14.
14. "Cooperative R&D Programs," op. cit., p. 12.

15. See: Suzuki, N., "Country Paper as the Development Scheme for Japanese Small and Medium Scale Industries" paper presented at the Expert Group Meeting for Exchange of Experiences on Technology Services Delivery Systems (TSDS), Manila, Philippines, 2-6 November, 1981. UNDP Document ID/W6.350/13, February 25, 1982. p. 8.
16. Productivity, op. cit., p. 14.; Buntten-Mines, et al., op. cit., p. 11.
17. "France. An Electronics Plan with Global Ambition," Business Week, May 31, 1982, p. 39.
18. "Cooperative R&D Programs," op. cit., p. 16.
19. "Europe. A Search for New Ways to Close the Technology Gap," Business Week, December 21, 1981, p. 52-53. (Hereinafter referred to as "Europe.")
20. Nations, Richard, "The Hi-tech Hijack," Far Eastern Economic Review, July 2, 1982, p. 72-73.
21. Vogel, op. cit., p. 32.
22. Productivity, op. cit., p. 10-11.
23. Ibid., p. 7.
24. "Cooperative R&D Programs," op. cit., p. 7.
25. SRI Industrial, "Assessment of U.S. Government Expert Financing of High Technology Products: Phase 1, Research Approach." Final Report. Menlo Park, CA: 1981, p. 1-2.
26. Vogel, op. cit., p. 32.
27. "Cooperative R&D Programs," op. cit., p. 2-4.
28. Peat, Marwick, Mitchell & Co. World, New York, NY, Spring, 1982, p. 18.
29. Productivity, op. cit., p. 44.
30. "Cooperative R&D Programs," op. cit., p. 12.
31. Ibid., p. 12.
32. Ramsey, Douglas, et al., "Japan's High Tech Challenge," Newsweek, August 9, 1982, p. 51.
33. Ibid.
34. Ibid., p. 52.

35. "What Can the U.S. Learn From its Rivals?", Business Week, June 30, 1980, p. 138-139.
36. "Cooperative R&D Programs," op. cit., p. 19.
37. "Europe," op. cit., p. 52.
38. Productivity, op. cit., p. 19.
39. Ibid., p. 7.
40. Ibid.
41. Ibid., p. 26.
42. Ibid., p. 26 and 30.
43. Ibid., p. 8.
44. "Cooperative R&D Programs," op. cit., p. 9.
45. Vogel, op. cit., p. 30.
46. "Cooperative R&D Programs," op. cit., p. 3.
47. Ramsey, op. cit., p. 49.
48. Nations, op. cit., p. 72.
49. Ibid., p. 76.
50. "Cooperative R&D Projects," op. cit., p. 2.
51. Ramsey, et al., op. cit., p. 48.
52. Productivity, op. cit., p. 8.
53. Vogel, op. cit., p. 30.
54. Productivity, op. cit., p. 40.
55. Ibid., p. 9.
56. Vogel, op. cit., p. 32.
57. Productivity, op. cit., p. 41.
58. Vogel, op. cit., p. 32.
59. Donlan, op. cit., p. 29.

BIBLIOGRAPHY

Blackburn, Mark, "Information Scramble". Far Eastern Economic Review, July 2, 1982, p. 72.

Bunten-Mines, Elaine, et al. "Cooperative R&D Programs to Stimulate Industrial Innovation in Selected Countries". Office of Cooperative Generic Technology, U.S. Department of Commerce, June, 1980.

Dahlby, Tracy. "Nissan Announces Martin Marietta Technology Swap", Daily Camera, August 26, 1982, p. 45.

Donlan, Thomas G. "Yen For Productivity", Barron's, August 2, 1982, p. 28-29.

Early, Steve. "Unions and Management in Europe Seek to Ease Transition to New Technology". Transatlantic Perspectives, Number Six, February, 1982, p. 20-24.

"Europe. A Search for Ways to Close the Technology Gap", Business Week, December 21, 1981, p. 52-53.

"FRANCE. An Electronics Plan With Global Ambition", Business Week, May 31, 1982, p. 39.

Gregory, Gene. "All's Fair in War". Far Eastern Economic Review, July 2, 1982, p. 76-77.

Gregory, Gene. "Japan's Industrial Revolution". The Futurist, August, 1982, p. 30-31.

Jones, Dorothy E. "Crying Wolf Over A Threat From Asia". Business Week, July 26, 1982, p. 6-7.

Nations, Richard, "The Hi-tech Hijack". Far Eastern Economic Review, July 2, 1982, p. 72-76.

Peat, Marwick, Mitchell & Co. World, New York, NY, Spring, 1982, p. 18.

Ramsey, Douglas, et al. "Japan's High-Tech Challenge". Newsweek, August 9, 1982, p. 48-54.

Schlie, T.W. "The Japanese Technological Challenge". Paper presented at the U.S. Department of Commerce Professional Communicators Workshop, May 21, 1982.

Schlie, Theodore W. "The Theoretical Basis for Governmental Support of R&D: Traditional Arguments and New Realities. Draft paper prepared for the Second U.S.-Japan Science Policy Seminar, Comparative Studies of Policies and Practices for Basic and Applied Science in Japan and the United States, Honolulu, Hawaii, August 24-26, 1981.

Suzuki, N. "Country Paper on the Development Scheme for Japanese Small and Medium Scale Industries". Paper presented at the Expert Group Meeting for Exchange of Experiences on Technology Services Delivery Systems (TSDS), Manila, Philippines, 2-6 November, 1981. UNDP Document ID/WG.350/13, February 25, 1982.

Tharp, Mike. "Spanner in the Works". Far Eastern Economic Review, July 2, 1982. p. 73-74.

U.S. Congress, House, Joint Economic Committee. Productivity. Washington, D.C.: U.S. Government Printing Office, 1979. Hearings before the Committee June 5, 1979.

U.S. Congress, House, Joint Economic Committee. U.S. Export Competitiveness. Washington, D.C., U.S. Government Printing Office, 1980. Hearings before the committee July 29, 1980.

U.S. Department of Commerce, Japan. The Government-Business Relationship. A Guide for the American Businessman. Washington, D.C.: February, 1972.

Vogel, Ezra F. "Can The Japanese Keep It Up?". The Innisbrook Papers, p. 30-32.

"What the U.S. Can Learn From Its Rivals", Business Week, June 30, 1980. p. 138-142.

APPENDIX D

Industry Perspectives on Technology Transfer

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INDUSTRY PERSPECTIVES ON TECHNOLOGY TRANSFER

DRI research staff interviewed executives from a variety of businesses including high technology (electronics, medical equipment), automobile and heavy manufacturing, engineering and product development and the investment capital field. Both large and small firms were represented. The purpose of these in-depth, semi-structured interviews was to obtain perspective from industry on the technology transfer challenges facing NASA and the competitive challenges facing the United States.

The areas of discussion included, but were not limited to, the following: changes in patterns of technology acquisition over the last 20 years; influences of foreign competition; channels of technology transfer; industrial patent policy; university linkages; and barriers or incentives to the transfer of technology or to innovation.

The structural differences between government and industry stand out clearly--one is politically responsive and the other responsive to market forces. However, even though these differences generate skepticism among managers of industry, there is strong interest in the possibilities for co-operation and a realization of what might be gained through searching for better ways to transfer or exchange technology.

Industry Perspective on Government Research and Development

Industry representatives generally believe that government-generated technology includes many innovations that would be attractive to industry although there is a feeling that government technology often is too expensive for commercial application without substantial (and expensive) adaptation. Those companies already in contact with NASA Centers such as Lewis

and Langley have had substantial success in obtaining valuable information and assistance. If industry and government cooperate in the transfer of information, the relationship is most effective when it is one of equals, with NASA scientists and engineers learning from counterparts in industrial laboratories, and vice versa.

The often adversarial relationship between government and industry needs to be overcome. There is a traditional perception, greatest in the non-aerospace and commercial sector, that government does not understand the needs of industry. One example is NASA's development of a one-of-a-kind spacecraft. Given that highly specialized and custom crafted expertise, the obvious questions asked by industrialists are: "How can NASA understand the problems of manufacturing 150 million silicon chips?" or "What does NASA know of the quality control problems of an automotive assembly line?"

NASA development experience is concentrated in technical avenues of science and engineering, and reflect little experience with industrial problem areas of marketing, manufacturing and competitive economics. Even some aerospace executives perceive NASA as "goldplating" or compulsively flight qualifying all hardware regardless of cost.

NASA was cast as typically proposing solutions to problems with little thought to cost or time constraints. Although this perception of high quality standards often is a positive one, it makes NASA solutions appear too expensive for commercial application without substantial modification. It was often stated by respondents that NASA's planning process appears to lack consideration of potential commercial impacts; a closer relationship with the affected sectors of industry would be welcomed to enhance potential technology transfer opportunities. Much of industry has little interest in R&D that is not clearly linked to products which fit a particular industry's market objectives.

In the best of all scenarios for industry, NASA would include in its planning priorities consideration of commercial opportunities and the steps necessary to bring an innovation to the point of operational readiness. It was recognized by industry officials that this might not be possible given NASA's mission-oriented goals. Suggestions were made for a "middleman" linking mechanism to be established outside commercial industry and government. This third party linkage might be found in a university setting or could be an independent entrepreneur familiar with both NASA research and industrial procedures. This linkage might overcome barriers between government and industry relating to style, organization and scale of costs.

Industry's Environment

As well as understanding the needs and problems of industry, interview respondents believed that any successful technology transfer program must also exhibit an awareness and sensitivity to industry constraints, so different from those of government. Industry measures innovative success in terms of profit dollars generated within a specified payback period. NASA's measure of success is more in terms of technical objectives met.

The costs of adaptation of a NASA-generated innovation add more burden to the cost formula. Industry leaders stressed that this adaptation, and in many cases redesign and engineering costs, often seem to be more than originally anticipated, which causes the shelving of worthwhile innovations. The more risk that the government can assume in product or process development, the more likely it will be that a firm will be in a position to accept the remaining cost risks of introducing a process or product into the commercial mainstream. Those costs of adaptation and introduction often were cited as being up to ten times the cost of the basic technology development.

If NASA could select a few projects for development to the operational stage (and provide some guarantee of exclusive rights), the ratio of successful application would be higher and generate stronger interest by industry.

Industrial representatives viewed government technology transfer activities as lacking in the marketing acumen essential for the industrial world. It was recognized that there is little incentive for NASA's scientists and engineers to become avid champions for the commercial marketing of their technology. Again, the need for an entrepreneur to match technology to needs often was mentioned.

Another problem for industry is generating capital for innovation. The most pessimistic view expressed was that the less government work a company engaged in, the better the chances for private venture capital for innovation. Particularly in the case of small businesses, there is a shortage of capital for applying government-generated technology. Because small companies often are not aware of areas of government interest, they miss out on innovative ideas and chances for contract awards that go to larger firms. Even highly qualified small engineering development firms cannot afford to keep current with NASA technical needs and cannot afford to risk investment in technology outside their narrow specialty areas. This could be changed if very modest funding for proposal preparation were made available by NASA in areas of specialized innovation needs.

Views on proprietary data issues were mixed. Most conceded that NASA needed to assure some type of exclusivity or competitive advantage. In one case example cited, a government laboratory released the technology for an implantable insulin pump and no company picked up the development option because exclusive rights were not offered. However, in the semiconductor industry, patents and licenses often have value only for use in a portfolio

for trading purposes. The technology is moving so rapidly that patents have little value as competitive safeguards. The leading companies in the micro-electronics industry concentrate on moving into an area rapidly, reaping the benefits and then licensing the technology to someone else after only a few years. Safeguarding industry proprietary information remains a concern in assessing risks attendant to joint or cooperative endeavors.

Channels of Communication

There was substantial agreement on the importance of personal communication in technology transfer. While some persons were familiar with NASA's formal Technology Utilization publications programs, such as NASA Tech Briefs, they accorded it little weight in comparison with person-to-person communication. Modest changes and ideas can be generated by paper-based information, but major transfer of information rarely occurs without sustained individual attention. The respondents strongly believe that personal networks and oral communication are the most effective way to secure appropriate information.

Personnel mobility also was mentioned frequently as a favored transfer mechanism. In fact, technology transfer within the semiconductor industry is fueled by frequent and competitive personnel transfer. One of the automobile industry executives stated that, in certain cases, a researcher will be relocated to a manufacturing division along with his innovation to see that it is implemented properly.

Informal networks, kept that way by design, are favored. This is true both within and outside a corporation. Several respondents offered the possibility of inviting NASA scientists and engineers to visit their facilities as well as visiting NASA laboratories. This accords with the historical evidence that American corporations consider themselves as "givers" of technology and not as "receivers." There appears to be a trend now in

American industry to be less reluctant to borrow ideas from others, perhaps a backing off from the "Not Invented Here" (NIH) syndrome. Even larger, high technology firms no longer are able to fully meet their own technology requirements through solely in-house efforts. There is considerably more pressure to move products or processes into the marketplace quickly and hence the willingness to buy or borrow what once might have been in-house-developed technology.

Participation in technical or professional conferences is a primary source of technology. Such meetings provide neutral ground for the exchange of information and ideas.

Global Technology Search

There is increasing recognition that U.S. industry is in global competition for markets as well as innovative ideas. All were in favor--some more cautiously than others--of an increased role for NASA in technology transfer in order to facilitate industry's competitive position. It was also noted that Congress may become more amenable to the idea of government providing technical and cooperative assistance to industry.

On the other hand, serious doubts were noted about American cultural incentive to cooperate. Japan appears to have better cooperative spirit, although no one thought a wholesale adoption of foreign solutions would bring a workable answer. Some spirit of cooperation has been shown by participation in university/industry consortia such as the University of Illinois' Fracture Control Program and MIT's Industrial Liaison Program. Membership in such programs usually must be justified as a way to generate income-producing technology rather than only supporting basic research. These programs have benefits to both parties, because the participation fees

can provide needed equipment to universities and industry access makes available industry operating knowledge to students. Such consortia drew praise as workable transfer mechanisms and as worthwhile for membership by NASA.

Another idea for cooperative activity involves industry officials working with NASA planning people to identify future areas of research. This arrangement would encourage constructive interaction on how NASA's research areas might complement industrial research areas. Although the substance of this suggests a Research Council, it could be extended to advertise future technology trends through publications read by key technical and industrial officials. If NASA scientists and engineers (and their technology) had a higher visibility in industrial publications, at association conferences and seminars, and in university consortia, it would establish a wider national network for exchange of technology.

Enhancing Technology Transfer

The industrial executives interviewed were skeptical about the depth of NASA's commitment to technology transfer, pointing to the small institutional budget. If technology transfer is an important objective, it needs to be provided with resources to match the rhetoric. These resources do not necessarily have to be allotted to the formal Technology Utilization Program. One suggestion mentioned by a former NASA official was to give each Field Center discretionary funds (an extremely valued incentive) based on the number of transfers achieved in a year's time.

The ideas of quantifiable measures of success and establishing goals and objectives for the program were favored. Among such were developing

articles for publication and membership in trade associations. Once the objectives are established, they need to be implemented by links to performance and salary reviews. It is the experience of industry that, unless objectives are rewarded in a formal evaluation, they will be neglected.

The technology transfer program needs greater visibility in NASA's hierarchy. Suggestions for achieving a greater presence ranged from dedication of a Field Center as "leads in transfer activities to the idea of designating technology transfer responsibility at the level of Associate Administrator. It will be a time-consuming process for NASA scientists and engineers generally to develop a sense of rapport with non-aerospace industry as a "user community" and technology transfer as an important priority. Support for this type of change must come from top NASA leadership backed by credible resources, and be sustained for a long enough period to permeate the NASA culture.

CORPORATE OFFICIALS INTERVIEWED

Andrew Adelman, Chief-Applications Division, Goddard Space Flight Center

Arthur Amman, Director-Research, Boettcher Company

Richard Baldwin, Vice President, Cargill Incorporated

G. Robertson Barker, Manager-Forest Research Information Systems, St. Regis Paper Company

R.W. Boeke, Senior Vice President-Component Design and Manufacturing, John Deere and Company

J.D. Brito, Research Planning and Coordination Group, John Deere and Company

John M. Budd, Jr., Manager of Business Relations, Solid State Product Center, Honeywell, Incorporated

Thomas J. Bulat, Manager-Research Planning and Coordination, John Deere and Company

Ron Byerly, Congressional Staffer, House Science and Technology Committee

William S. Coleman, General Manager-Research Center, Eaton Corporation

Carlos A. de Moraes, President, Custom Engineering, Incorporated

Lamont Eltinge, Vice President-Research, Eaton Corporation

Robert Frosch, Vice President-Research, General Motors Corporation

Richard H. Frost, President, Frost Engineering Development Corporation

Dale R. Galliart, Manager-Metals Research, John Deere and Company

James A. Graham, Senior Research Associate, John Deere and Company

Lawrence W. Greenwood, Assistant Director, Commercial Space Systems, Aerospace Systems Division, Ball Brothers

Charles Gwyn, Assistant General Manager, United Technologies-Microelectronics Center

John Heightley, President, Inmos Corporation

George Huebner, former Vice President, Chrysler Corporation

Caleb Hurtt, President, Martin Marietta Aerospace

Len Jaffe, former Deputy Associate Administrator-Applications, NASA

Joseph Janette, Head-FAA Program, IBM

Alfred A. Jeffries, Director, Special Projects and Support Services,
TRW Electronic Products, Inc.

Thomas L. Kelley, General Manager, Hewlett Packard Corporation-Greeley
Division

Donn D. Lobdell, Vice President-Research and Development, Cobe
Laboratories, Inc.

David MacKenzie, Manager-Minerals, Marathon Oil Corporation

Richard McCurdy, former President, Shell Oil Company

Robert Mercure, Vice President, Colorado Venture Associates

Gordon Millar, Vice President-Engineering, John Deere and Company

Robert Porter, President, EarthSat Corporation

Floyd Roberson, former Chief-Technology Transfer Division, NASA

Thomas Rogers, former Assistant Secretary-R&D, Housing and Urban Development

Margaret Roberts, Director-Research Planning, Ford Motor Company

Robert D. Strunk, Manager-Engineering Science, John Deere and Company

John Townshend, President, Fairchild Space Electronics

Robert B. Wismer, Technical Center Director, John Deere and Company

William P. Wohlford, Advanced Machine Concepts Group, Technical Center,
John Deere and Company

Bevan P. Wu, Manager-New Product Automation, Information Systems Division,
IBM

APPENDIX E

Selected Governmental Policies Affecting Technological Innovation
in the American Economy

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Selected Governmental Policies Affecting Technological
Innovation in the American Economy

Technological innovation is essential to a healthy, growing economy. Government interest in promoting such innovation is self-evident. However, innovation is a complex and not completely understood phenomenon. While the general factors leading to successful innovation can be identified, there is no set formula assuring its achievement.

The governments of the industrialized nations have taken widely differing approaches to promoting technological innovation, ranging from the very active role of the Japanese government to the more passive role of the U.S. government. In Japan, economic development has been directly identified with technological development, and government policies and resources are specifically directed toward supporting this technological development. The United States, however, has never developed a coherent policy regarding technological development and innovation. Instead there are a wide variety of policies that affect innovation, few of which consciously consider that effect.

First there are the general macroeconomic policies that affect the overall health of the economy. To the degree that these policies help to create a strong and growing economy and engender a feeling of confidence in the country's economic future, innovation is encouraged. Although obviously critical, these policies are outside the scope of this paper.

A second set of policies includes those generally created for purposes other than promoting innovation but which may directly and significantly affect that process. Those policies that adversely affect technological innovation need to be reviewed to determine if their objectives can be achieved in other ways. As examples of this set of policies, antitrust laws, environmental regulation, the Freedom of Information Act, and organizational

Finally, there are policies that are created, at least in part, to promote innovation. Such policies need to be reviewed to determine their effectiveness. Those found to be effective (and that meet other public policy objectives) should be considered for expansion. Those found not to be effective should be changed, or perhaps eliminated. In this paper, patent policies, tax policies related to innovation, and policies regarding procurement and direct federal support of research and development are reviewed as examples.

In the past decade, the relationship between government policies and technological innovation has been much examined.¹ This paper draws heavily on the body of knowledge that has been developed in this process. In some areas, it is apparent that this intensive analysis has already yielded tangible results. In other areas, particularly where the issues are more complex and controversial, there is still much to be done.

¹ See for example:

- Arthur D. Little, Inc. and Industrial Research Institute, Inc., Barriers to Innovation in Industry: Opportunities for Public Policy Changes, Washington, D.C.: National Science Foundation, Sept. 1973.
- R.G. Noll, et al., Government Policies and Technological Innovation, Pasadena: California Institute of Technology, 1974.
- Office of Technology Assessment, Government Involvement in the Innovation Process, Washington, D.C.: Government Printing Office, 1978.
- Advisory Committee on Industrial Innovation, Final Report, Washington, D.C.: U.S. Department of Commerce, Sept. 1979.

U.S. Tax Policies²

Tax policies can act as a spur to innovation in a number of ways. They can provide favorable treatment of research and development (R&D) expenditures. They can provide favorable treatment for income gained as a result of successful R&D. They can encourage capital investment generally. They can encourage the start-up of new companies interested in funding new, high-risk ventures. As such, these policies act as an incentive to encourage private uses of funds. Minimal government involvement is required. Decision making remains in the private sector. On the other hand, there is no assurance that these incentives will actually produce the desired private actions.

Research and Development Incentives

Present U.S. tax policies targeted most specifically at encouraging innovation relate to treatment of research and development expenditures. Firms are permitted to fully deduct the noncapital costs associated with research and development in the year in which they occur. Since this immediate expensing reduces taxable income, a tax savings is realized. The net effect is to lower the effective cost of and thus encourage R&D.

²The information in this section is drawn largely from:
● Mansfield, Edwin, "Tax Policy and Innovation," Science, Vol. 215, 12 March 1982, pp. 1365-1371,
and
● Cordes, Joseph J., The Impact of Tax and Financial Regulatory Policies on Industrial Innovation, Washington, D.C.: National Academy of Science, 1980.

To encourage increased R&D, the Economic Recovery Tax Act of 1981 authorized a 25 percent tax credit for certain R&D expenditures which exceed the average expenditures incurred by a firm during a preceeding "base" period (generally the previous three years). A tax credit is a strong incentive since it reduces not just taxable income but the taxes themselves. This provision expires in 1986.

Capital Investment Incentives

Since the early 1960's the tax laws have been modified several times in an effort to encourage capital investment. These modifications are especially important since many economists believe that new capital investment in plant and equipment is the primary moving force in technological change.³ Two general approaches have been taken. One has been to allow the use of accelerated methods of depreciation so that (compared to traditional depreciation methods) recovery of the investment is speeded up, thus lowering taxes and increasing cash flows more immediately following the investment. The 1981 Tax Act simplified and greatly speeded up depreciation schedules so that most types of R&D capital equipment may now be fully depreciated in three years and most other capital equipment in five years.

The second major approach has been to allow a tax credit to be taken for a specified percentage of the investment for new capital equipment. The 1978 Tax Act permanently enacted the existing 10 percent investment tax credit and allowed corporations to use the credit to offset up to 90

³See for example, J. Schmookler, Invention and Economic Growth, Cambridge, Mass.: Harvard University Press, 1966.

percent of their income tax requirements. Thus a firm making a \$1 million capital investment is able to directly reduce its income taxes by \$100,000. This tax savings effectively reduces the cost of the investment.

New Business Incentives

New firms are often cited as the source of much innovative activity. Therefore, tax provisions encouraging the startup of new firms, especially those oriented toward investing in new technological development, may be considered to encourage innovation. An important source of funds for new, high-technology companies is the "venture capital" industry. This industry has expanded substantially in recent years because of the special tax treatment allowed for income returned to shareholders of qualifying companies.⁴

Another important source of funding for new businesses is the Small Business Investment Company (SBIC), as authorized by the Small Business Investment Act of 1958. After meeting certain SBIC requirements, a company may be able to access low-cost funds from the Small Business Administration thus leveraging its existing capital base. It also receives certain tax advantages primarily relating to losses on stock and debenture investments (it may fully deduct these losses). SBICs are also very active in high-technology oriented investments.

⁴Normally, a corporation pays taxes on its income and then the shareholders also pay taxes on the income that is distributed as dividends. However, venture capital companies satisfying the requirements of the Securities and Exchange Commission that they provide capital only to firms primarily involved in developing new products, processes and technology need not pay taxes on the income that is distributed to stockholders.

A third organizational arrangement that has become a source of funds for new technology-based firms is one where a corporation with no more than 25 stockholders qualifies for treatment according to subchapter S of the tax code. To do this, the corporation must (among other requirements) be domestic, must have all individual stockholders, and must get no more than 20 percent of its revenues from passive investment income. A subchapter S corporation enjoys the limited liability of a corporation but its earnings are not taxed until they are distributed to the stockholders. There are certain other tax advantages as well.

Another approach that has been suggested is the use of an R&D limited partnership.⁵ A limited partnership is a statutorily-authorized means under which an investor can participate as an owner in a partnership but with his liability limited to his investment. Such limited partners may not take part in the actual control of the business. The tax advantage of a partnership arrangement is that partnership income, losses, deductions and credits pass through directly to the partners. In the case of an R&D limited partnership, it appears that partnership expenditures for R&D activities may be deductible from the individual incomes of the partners and that any income realized from the sale of a successfully developed invention may be treated as capital gains income.

⁵James K. La Fleur, The R&D Limited Partnership: A Financial Break-through for Inventors and Small Businesses, Los Angeles, Calif., 1981.

Finally, a loss from a transaction involving "small business stock" may, under specified conditions, be treated as an ordinary loss rather than a capital loss. This has the effect of allowing a larger tax reduction and may encourage more investment in new small businesses.

Other Proposals

In addition to these existing tax incentives, there are a variety of other proposals. Many relate to tax reform issues generally such as lowering the capital gains taxes and eliminating the double taxation of corporate income paid as dividends to stockholders. Others are targeted at encouraging investment in small, technology-based firms such as allowing the returns from investments in such companies to be "rolled over" on a tax-free basis into other similar investments. Still others are directed at stimulating R&D. An example is the proposal to allow immediate write off of expenses for capital assets acquired for R&D purposes.

Conclusion

Generally U.S. tax policies have provided favorable incentives for R&D activities, including provisions for a variety of organizational arrangements designed to promote innovation and technological development by new businesses. Direct government involvement can be kept at a minimum, while the use of private funds is encouraged through such existing tax policies and proposed tax reforms.

U.S. Patent Policies

Article One of the U.S. Constitution authorizes Congress to "promote the progress of science and the useful arts by securing for limited terms to authors and inventors the exclusive right to their respective writings and discoveries." Since 1861, U.S. patent law has granted this exclusive

right to make use of patent inventions for a 17-year period. Patent rights have traditionally been considered to be a major incentive for innovation since they allow the developer of a new invention the opportunity to exclusively benefit from its commercial use during this period. In recent years, a number of issues regarding the patent system have been raised, leading to greatly renewed Congressional attention and activity.

Inventions Made With Federal Funding

One important area concerns the ownership of inventions made by non-government entities while conducting federally funded research and development. Early policy statements tended to support government ownership of patent rights in such situations. However, a 1971 statement by President Nixon authorized federal agencies to grant patent ownership or exclusive use "where it is deemed necessary to create an incentive for further development and marketing."⁶

Interpretation of this policy varied widely within different parts of the federal government. In 1979 Congressional hearings, it was reported that various Executive agencies were using approximately 20 different patent arrangements.⁷ In 1980, Congress established a uniform policy in this area with the passage of Public Law 96-517. This law gives nonprofit organizations (including universities) and small businesses the ability to retain title to inventions made in performance of government-sponsored grants and contracts.⁸

⁶Background Materials on Government Patent Policies, Committee on Science and Technology, U.S. House of Representatives, Washington, D.C., 1976, p. 17.

⁷Testimony of the GAO Comptroller General, Hearings on S.414, Committee on the Judiciary, 96th Cong., 1st Session, May 1979.

⁸On February 18, 1983, President Reagan issued a memorandum that effectively extends this policy to large businesses as well.

Adequacy of Patent Life

A second issue is the sufficiency of the 17-year period. The pharmaceutical industry especially has argued that this term is inadequate since government premarket clearance procedures of new drug products are so lengthy that the effective period of protection is far less.⁹ In 1981, the Senate passed a bill that would extend the term for agricultural chemicals and pharmaceuticals for up to seven years. The House is presently considering a similar bill.

Patent Reliability

A third issue is the reliability of the protection afforded by a patent. It has been pointed out that "the courts, when in doubt, tend to rule against the patent system and declare the patent invalid."¹⁰ In part, this is probably a reflection of a certain bias against the monopoly status granted by a patent. However, it also is a reflection of the complexity of those cases. Patent case decisions have varied widely among the different circuit courts in the U.S. In 1982, Congress passed a bill creating a central court of appeals for all patent cases coming from federal district courts. It is hoped that this will bring greater uniformity in patent decisions.

Conclusion

The effectiveness of the patent system itself has been generally called into question. The procedure for obtaining a patent has become

⁹ See, Office of Technology Assessment, Patent-Term Extension and the Pharmaceutical Industry, Washington, D.C., 1981.

¹⁰ Judith Obermayer, The Role of Patents in the Commercialization of New Technology for Small Innovative Companies, Cambridge, Mass.: Research & Planning, Inc., 1982, p. 2.

increasingly complex and costly. In some areas, the technologies change so rapidly that companies do not bother to go through the patent process. Congress has been unusually active in the patent area in recent years.¹¹ Most of the attention to this point has focused on patchwork corrections to the existing system. It may be that the time has come for a more fundamental reassessment of the efficacy of this system.

U.S. Antitrust Policies

The antitrust activities of the U.S. government are intended to encourage a competitive economy. Although the primary benefit of competition concerns prices, it is also considered an important spur to innovation. Thus, to the degree that antitrust policy is successful in promoting competition it may also be a favorable force in the innovation process. The one major study that has been undertaken on this subject, however, suggested that in some cases the actual effect of antitrust enforcement has not been favorable and that improvements are warranted.¹²

Market Structure and Innovations

The original thrust of antitrust policy was to break up monopoly control of markets. The model of perfect competition, at the center of classical economic thought, showed that the ideal market involved a large number of sellers (as well as buyers), none of whom possessed any special form of market control. A school of economists, led by Joseph Schumpeter,

¹¹In addition to those areas already mentioned, Congress is also considering legislation that would increase the fees paid in the patent process with the increased revenues going to expand and modernize the Patent and Trademark Office

¹²Ginsburg, Douglas H., Antitrust, Uncertainty, and Technological Innovation, Washington, D.C.: National Academy of Sciences, 1980.

challenged this model and asserted that "large size and some monopoly (i.e. market) power are prerequisites for economic growth through technological progress."¹³

Considerable study of the relationship between market structure and innovation has occurred in the last several decades. While the findings are neither uniform nor conclusive, it is clear that the classical model of a perfectly competitive market is not conducive to innovation. The availability of some market power to be able to take advantage of an innovation appears to be an important incentive. On the other hand, barriers to entry in a market can reduce the incentive to innovate. Beyond these rather general statements, little else can be asserted conclusively.

Constraints to Success

Antitrust policy has recognized that the size of a firm or the concentration of the market in which it operates are not the primary indications of antitrust violations. Thus, it is often said that "size alone is no offense." But if size is not an offense, it has certainly been grounds for suspicion. Similarly, firms operating in concentrated markets (so-called oligopolistic markets) are scrutinized carefully. In such markets, there is some question about whether antitrust policy allows a firm to be "too" successful if the effect is to further concentrate that market. The U.S. automobile industry was a good example of this situation

¹³ Ibid., at 10.

for many years during which General Motors had to be careful not to dominate the market so much that it would become subject to a dissolution proceeding. Foreign competition has now changed this situation considerably.

The uncertainty that antitrust policy poses for otherwise legitimate competitive actions is illustrated by a recent action by the Federal Trade Commission (FTC) against E.I. du Pont de Nemours & Co. Du Pont had developed an innovative production technique that gave it a substantial cost advantage in the titanium dioxide (TiO_2) pigment market. The FTC complained that du Pont, by greatly expanding its production capacity to take advantage of this cost advantage, had "unlawfully" attempted to monopolize this market.

As Ginsberg quite cautiously concluded:

If the FTC staff's views--that du Pont violated the law at least in part, by reason of its rapid expansion of capacity to exploit a new and cheaper way of making TiO_2 --prevails, then the line between successful technological innovations and unlawful means of commercializing and exploiting that innovation will have been substantially blurred.¹⁴

Joint Ventures for Research and Development

Another point of interface between antitrust policy and innovation that has received substantial attention in recent years concerns joint ventures between firms for research and development. Joint R&D efforts have increased in popularity for a number of reasons:

¹⁴Ginsburg, op.cit., p. 23.

Economic pressures stemming from growing difficulty of private industry to produce profits from R&D spending are a principal stimulus to cooperation. By combining research efforts, the excessive costs associated with many projects can be distributed among participating firms. Individual firms unwilling or financially unable to assume speculative risks associated with long-term basic research projects necessary for the technological advancement of their industry can utilize joint research ventures to share these risks. Cooperation in conducting research can also avoid needless and costly duplication resulting from competition in the development of new products.¹⁵

In spite of these potential economic advantages, it has been suggested that the use of such joint ventures has been limited due to concerns about antitrust violations. For example, in the report of the Advisory Committee on Industrial Innovation during the Carter Administration it was stated that "proposals for technically meritorious joint research projects were discouraged by legal counsel because of the uncertain possibility of future antitrust attack. In each such case joint research did not occur, and the research was not undertaken at the individual firm's level."¹⁶

The Sherman Act, centerpiece of U.S. antitrust policy since its passage in 1890, begins by stating that "every contract, combination. . . or conspiracy in restraint of trade" is unlawful. Thus if an arrangement between two or more companies has the effect of restraining trade, i.e., reducing competition, then that arrangement is a violation of the provision. Technological innovation is an important source of competition in many industries. It is not surprising, therefore, that the Antitrust Division of the Justice Department has approached joint research efforts with caution.

¹⁵ Note, Joint Research Ventures Under the Antitrust Laws, George Washington Law Review, Vol. 39, pp. 1112-1113, July 1971.

¹⁶ Advisory Committee on Industrial Innovation, Final Report, U.S. Department of Commerce, September 1979, p. 107.

Antitrust Guide

In an attempt to clarify its position, the Antitrust Division published an Antitrust Guide Concerning Research Joint Ventures in November 1980. It takes the approach of setting out the analytic procedure that the Division uses to evaluate the antitrust implications of such joint arrangements. The key factors in the evaluation are

the nature of the proposed research, the joint venturers, the industry and the restraints on conduct imposed in connection with the project. In general, the closer the joint activity is to the basic research end of the research spectrum--i.e., the farther removed it is from substantial market effects and developmental issues--the more likely it is to be acceptable under the antitrust laws. Also, the greater the number of actual and potential competitors in an industry, the more likely that a joint research project will not unreasonably restrain competition. And, the narrower the field of joint activity and the more limited the collateral restraints involved, the greater the chances that the project will not offend the antitrust laws.¹⁷

Two other relevant issues concern collateral restrictions involving the joint ventures or outsiders and limitations on access to the joint venture or to its results. In general, collateral restraints must be necessary for the success of the venture and must not have significant anticompetitive impact.¹⁸ Acceptable collateral restraints could include the obligations to exchange any results from research undertaken previously in the field of joint research and the duty not to disclose results of the joint research to outside parties until patents are obtained.

¹⁷"Antitrust Guide for Joint Research Programs," Research Management, Vol. 24, No. 2, March 1981, pp. 30-31.

¹⁸Ibid., p. 34.

Regarding access to the venture, the Guide states that

if a joint research venture becomes the key to competing effectively in markets served by the participants, and if the research effort is not practicably or effectively duplicable by excluded firms, access to the venture, (or to its results, if participation itself is not essential) on reasonable terms may be mandated by the Sherman Act.¹⁹

Again, it is emphasized that the more basic the research, the less concern there will be regarding access.

In conjunction with the publication of the Guide, the Justice Department has sought to convey the message that it is not opposed to joint research. For example, in a 1980 presentation the then deputy assistant attorney general of the Justice Department stated that

antitrust laws do allow significant cooperation among firms, even major competitors, where necessary for research and development of new technology. While there are literally thousands of joint ventures, operating in the fields of research and development, few have been attacked under the antitrust laws. The Justice Department has never challenged a pure research joint project--that is, a project devoted solely to research and involving no collateral restrictions. The Department has challenged only three research joint ventures in the last two decades--and each involved significant collateral restraints which retarded innovation.²⁰

To further reduce uncertainty in this area, the Justice Department has encouraged the use of the "Business Review Procedure," a mechanism under which it will review a proposed joint activity and effectively approve or disapprove it. For reasons which are not clear, only 21 such reviews have been requested since 1968.²¹

¹⁹ Ibid., p. 35.

²⁰ Ewing, Ky. P., Jr., "Joint Research, Antitrust, and Innovation," Research Management, Vol. 24, No. 2, March 1981, p. 27.

²¹ Ibid., p. 33.

Industry Research Ventures

An important development in recent years has been the creation of several industry-wide research organizations. While the forms vary, the intention is to encourage research in areas basic to the respective industries. An early example was the Electric Power Research Institute, founded by electric utilities throughout the country to conduct research on a wide variety of matters of importance to this industry. The Gas Research Institute is a similar organization created to conduct research for the natural gas distribution industry. Since these industries are regulated monopolies, such research activities do not raise antitrust questions.

A somewhat different approach has been taken recently by a group comprised of manufacturers and users of semiconductors. Called the Semiconductor Research Cooperative (SRC), it is an independent organization established to generate a pool of funds, equipment and technical personnel that will be used to support basic research requirements for the semiconductor industry. This cooperative approach is seen as a response to similar cooperative efforts being undertaken in Japan and Europe. The SRC is expected to become a major source of funding for such research at selected university centers. Membership arrangements include the following aspects:

Corporations that join SRC will contribute amounts based on their worldwide sales or purchases of semiconductors. In return, they will receive progress reports on the work SRC sponsors and, although patent policies have yet to be worked out in detail, they will almost certainly get royalty-free licenses to use patented processes that arise from SRC projects. This arrangement means that every member company will have access to the entire pool of SRC-sponsored research, and small companies will pay less than large ones for that access.²²

²²Colin Norman, "Electronics Firms Plug Into the Universities," Science, Vol. 217, 6 August 1982, p. 514.

According to a recent article in Fortune magazine, "Perhaps the most positive contribution government can make to American innovation and export competitiveness would be to facilitate rather than discourage this kind of joint research."²³

Still another unique cooperative arrangement is the Microelectronics & Computer Technology Corp. This newly-formed organization is a for-profit joint venture of 15 companies that will sponsor and conduct research in such areas as computer-aided design, integrated circuits, software, and advanced computer designs. It is expected to have a budget of between \$50 million and \$100 million. The Justice Department has found this arrangement acceptable under its business review procedure, leading some commentators to conclude that cooperative arrangements will be given greater leeway than in the past.²⁴

Patent Licensing

Finally, there is the issue of antitrust policy as it affects patents--especially patent licensing. Patent law represents a special exception to the general antimonopoly policy. Clearly, however, a patent may not be misused in illegal ways to expand the force of the monopoly. For example, patent licensing agreements that also contain some form of restraints of trade such as fixing the price at which the final product may be sold are not protected by the patent laws and have been directly opposed by the Justice Department. On the other hand, the degree to which a company

²³Tom Alexander, "The Right Remedy for R&D Lag," Fortune, January 25, 1982, p. 68.

²⁴"IBM and Intel link up to fend off Japan," Business Week, Jan. 10, 1983, p. 98.

can continue to hold its monopoly following expiration of its basic patents by means of additional key improvement patents is still a matter of considerable uncertainty. An FTC complaint against Xerox Corporation on this issue was settled by consent decree, leaving the matter unsettled.

Conclusion

Not surprisingly, the Justice Department sees antitrust policy as being pro-innovation: "Antitrust policy strives, therefore, to keep markets competitive in order to promote innovation, and to encourage innovation in order to promote competition."²⁵ Yet it is clear that innovation has flourished in places like Japan where there is no such antitrust policy. U.S. industry is facing increasingly stiff international competition both in home markets and around the world. U.S. antitrust policies were formulated and developed at a time when this international competition was virtually nonexistent. Moreover, this international competition has resulted in no small part from the active support and involvement of the governments where these foreign firms are located. In this changing context, U.S. antitrust policy may be in need of broad-ranging reassessment to assure that U.S. firms are not operating at an unnecessary disadvantage and that valuable innovation is not being discouraged.

Government Regulation

In general, regulation is used to achieve a public policy objective that is not being fulfilled under normal free market conditions. Originally, regulation was directed at situations where normal competition was

²⁵ Antitrust Guide Concerning Research Joint Ventures, p. 3.

considered to be undesirable--primarily in the areas of transportation and utility service. This regulation was economic in nature and simply created a set of special conditions regarding market entry, product prices and other forms of competition in these industries. More recently, the use of regulation has been greatly expanded to pursue other objectives relating to pollution control, health and safety in the workplace and consumer product safety. Taken together, it is now clear that regulation is a major factor in the U.S. economy.

Regulation and Innovation

The impacts of government regulation on business and industry have been widely discussed and analyzed in recent years. Relatively little of this analysis, however, has concerned itself with effects on technological innovation. Nor is this a simple matter. One report has concluded:

The effect of regulation on technological innovation remains highly controversial. The research which has been undertaken in this area indicates that the effects which exist, though substantial cannot be simply characterized. At a minimum, it is necessary to recognize both positive and negative impacts and to distinguish the effects of regulation on the development of new compliance technology from the more general effects that it may have on the rate and direction of technological innovation in the broad sense.²⁶

The diversity of regulations is so great and the effects on different industries (and even different companies within given industries) are so variable that it is difficult to generalize. Indeed, most of the studies of this subject have followed the approach of analyzing individual industries.

²⁶Office of Technology Assessment, Government Involvement in the Innovative Process, 1978, p. 7.

Competitive Effects

It is possible to point to some general factors. First, regulation is likely to increase the cost of doing business. In many cases, those increased costs are substantial. The funds to comply with regulation must be diverted from some other application, presumably a profit-making one. Firms have an incentive to achieve compliance at the least possible cost. Within a given industry, higher profit firms with larger sales suffer less from regulation than do their smaller competitors. This is because the larger company can spread out the costs of compliance among more units and thus increase its unit price less to cover these costs.²⁷ In this way regulation may give larger companies a competitive advantage. In turn, this may make it more difficult for smaller companies to find the funds needed to develop innovative production techniques and innovative products.

Of course, considering only the compliance costs neglects the value of the regulatory outcomes. For example, if human health, productivity and longevity are bettered by requiring reductions in pollution, then the costs may be considered well worthwhile. Moreover, regulation produces a demand for the technology needed to achieve compliance. This demand may be the source of important innovation. Indeed, industries have developed in response to pollution control and worker safety requirements that are actively seeking to develop products and techniques that will allow compliance at the lowest cost.

²⁷See, for example, Clarkson, Kadlec and Laffer, "Regulating Chrysler Out of Business?," Regulation, September/October 1979.

Thus it may be that regulation has not so much impeded innovation as changed the nature and direction of innovation from merely focusing on developing products and production processes to other efforts. If this is indeed the case, presumably it is a reflection of our desires to make improvements in these other areas.

Regulatory Approaches

Regulation can be accomplished in a variety of ways. The most common approach taken has been to dictate a performance standard to which a regulated firm must adhere. While directly controlling performance may in itself achieve the desired objective, often it is just assumed that this will be the result. In many cases, however, the relationship between an activity and the desired objective is not well understood. Required performance procedures that do little to achieve objectives are obviously undesirable. Yet government has often gone ahead and required specific types of performance in spite of a lack of knowledge about their real effectiveness.

The general alternative to this approach is to require the outcome and leave the choice of the means up to the regulated entities. The primary advantage to this approach is that it allows those who know the problem best to devise the most cost-effective ways to overcome it. The primary disadvantage to this approach is that enforcement is very difficult and compliance is likely to be highly uneven. Short of incorporating major changes such as a marketable permit system or emission charges, such an approach has generally been considered acceptable only when tied together with specific performance standards as well.²⁸

²⁸For a good discussion of these alternatives, see Tom Alexander, "A Simpler Path to a Cleaner Environment," Fortune, May 4, 1981, p. 234.

Effect of Regulation on Technology

Most regulatory standards are developed on the basis of what can be achieved by existing technology. For example, the 1970 Clean Air Act requires that new stationary sources of air pollution use the "best available control technology" [emphasis added] and the Federal Water Pollution Control Act Amendments of 1972 require that industrial polluters use the "best practicable control technology currently available" [emphasis added]. The interpretation of these standards is left to the Environmental Protection Agency (EPA) which must assess the pollution reduction capabilities of existing technology.

In effect, when the EPA establishes standards based on what it determines to be the best available technology, it is also selecting the technology that should be used. While a firm may legally use a different technology, if it fails to meet the standards it certainly will be penalized. On the other hand, if it uses the EPA-chosen technology and does not meet the standards it may be able to avoid these penalties.²⁹

Moreover, because the EPA has tended to change its standards, it has not benefited companies to be in the lead in adopting a particular technology. Rather, there is an incentive with this system to continue to operate old facilities and postpone building new ones (to which more stringent standards apply) until the final performance standards are established and the technology to achieve those standards is demonstrated.

In spite of these disincentives in the system, it is clear that regulation can act to spur technology development. In cases where the need has

²⁹ Wesley A. Magat, "The Effects of Environmental Regulation on Innovation," Law and Contemporary Problems, Vol. 43:1, Winter/Spring 1979, p. 18.

been considered great, it has even been used to "force" that development. A prominent example is provided in the case of emissions controls for automobiles. In the 1970 Clean Air Act, Congress legislated the requirement that new automobiles manufactured in 1975 achieve a 90 percent reduction in hydrocarbons and carbon monoxide emission, even though the technology for its achievement was not yet available.

This approach produced mixed results. In fact, emissions from new automobiles have been reduced considerably, though not in the time or by the amount originally required by Congress. On the other hand, it has been pointed out that this hurry-up approach caused the U.S. automotive companies to go with the catalytic converter, a more obvious but also more expensive approach than a redesigned engine such as was successfully developed by Honda.³⁰

In another example, the EPA decided that flue gas desulfurization (scrubbing) was the best approach to removing sulfur dioxides in emissions from coal-fired electric power plants. In 1971, EPA established its sulfur dioxide standard based on its determination that scrubbing removes 70 percent of the sulfur dioxides. At the time this standard was established, three scrubbers were in operation. The oldest, built in 1968, was abandoned by the end of 1971.³¹ The electric utility industry complained that not only was the technology unproved but also that it was unreliable, expensive, and the creator of substantial amounts of its own pollution (a waste sludge).

³⁰In fact, Chrysler developed a "lean burn" engine that would have satisfied emission standards only slightly less stringent than were finally established. See, Clarkson et al., op. cit., p. 46.

³¹Bruce Ackerman and W. Hassler, "Beyond the New Deal: Coal and the Clean Air Act," Yale Law Journal, Vol. 89, 1980.

While scrubber technology has been improved in the last decade, it has been pointed out that the incentive to develop alternative, potentially more desirable approaches such as fluidized bed combustion is reduced.

Conclusion

When a regulatory approach is adopted to achieve some desired objective, there is an implicit presumption that the benefits will outweigh the costs. However, the hoped-for benefits are often given more attention than the costs. And, indeed, enough experience with newer regulatory schemes is just being gained to be able to understand the nature and extent of some of these costs. For example, recent studies of the U.S. pharmaceutical industry have pointed to some alarming trends related to innovations including:

- increased costs and lower yields on new drug introductions
- declining rates of new product introductions
- fewer independent sources and increased concentration of new chemical entity (NCE) introductions
- declining growth rates for domestic R&D and shifts in R&D abroad
- NCE introductions available abroad before the United States.³²

While regulation alone is not responsible for these trends, it does appear to be a major factor.

Furthermore, a survey conducted by Edwin Mansfield of the University of Pennsylvania of over 100 firms accounting for about one half of all industrial R&D expenditures in the United States showing a decline in basic research expenditures between 1967 and 1977 in nearly every industry received this explanation:

³²These studies are summarized and discussed in Grabowski, Henry E., and J.M. Vernon, The Impact of Regulation on Industrial Innovation, Washington, D.C.: National Academy of Sciences, 1979, pp. 16-19.

When asked why they reduced the proportion of their R&D expenditures going for basic research and relatively risky projects, the reason most frequently given by the firms was the increase in government regulations, which they felt had reduced the profitability of such projects.³³

Congress has been considering a bill (S.1080) that would require federal agencies to complete a formal cost-benefit analysis for any new major regulation. While cost-benefit analysis is no answer in itself, it may be helpful in requiring agencies to consider all of the known and knowable implications of new regulations including their effects on innovation. Presumably, as with an environmental impact statement, if the consequences are found to be too adverse, either mitigating changes will be made or the regulation will not be promulgated. While major regulatory reform appears unlikely at this time, some balance of regulatory objectives with other economic objectives including technological innovation is clearly essential.

Federal Procurement and Direct Support of Research and Development

In a report done for the Office of Technology Assessment, it was concluded that two of the most effective policies in influencing the rate and direction of technological change are federal R&D support and procurement of innovative technology-based products.³⁴ Research and development is essential for innovation. While private industry is motivated by competition to engage in R&D, the long lead times, high risk and substantial expense have been thought to require government funding as well.

³³ Edwin Mansfield, "Comments" in Towards an Explanation of Economic Growth, Symposium 1980, University of Kiel, 1981, p. 146.

³⁴ Office of Technology Assessment, Government Involvement in the Innovation Press, Washington, D.C., 1978, p. 4.

Funding for R&D

Originally, U.S. government support was directed toward strengthening the science and technology infrastructure as in the case of support for education and toward developing knowledge and products for its own use as in the case of national defense. The level of government support remained modest until World War II demonstrated the central role of science and technology in society. Since then, government support of R&D has increased dramatically. At this point, roughly half of all R&D performed in the U.S. is funded by the federal government.³⁵ About 15 percent of all R&D is performed at federal laboratories and centers.

Procurement

In addition to this direct support of R&D, federal procurement activities often have indirectly supported the R&D necessary to supply the product desired by government. Government purchases can represent a major guaranteed market that reduces the risk of product development and assures sufficient sales to make that development worthwhile. Since the government is the user, it can provide clear directions for the research and development needed.

The combination of R&D support and procurement has been found to have had a major influence on technological development in areas such as the electronics industry:

³⁵It should be noted that this share is down considerably from the early 1960's when government funding accounted for about 65 percent of total U.S. R&D expenditures. R. Piekarz, E. Thomas and D. Jennings, "International Comparisons of Research and Development Expenditures," National Science Foundation: Washington, D.C., Jan. 6, 1983, Table 1.

The U.S. government used, in order to stimulate innovation in the electronic industry, various instruments: e.g. financial support for R&D, procurement incentives and it created a general climate favourable to innovation. The mix of these three instruments was the most important reason for the successfulness of the project. Direct R&D subsidies were given, and companies were sure to find a willing purchaser. Companies even funded several times as much R&D support as has been funded by DOD. This was due to the fact that the government, by its procurement policies and by creating a favourable climate, reduced³⁶ uncertainty at the demand side of firms considerably.

Most of the writing in this area emphasizes that government support has been important in product development and diffusion rather than in invention. However, it is also pointed out that some government (especially DOD) practices encouraged new companies to become suppliers, thereby promoting an important source of innovation.³⁷

Civilian R&D

Direct federal support of innovation through R&D and procurement has been most successful where government was itself the primary user of the desired product. And, in fact, until fairly recently, most government-supported R&D was of this type--primarily in the areas of defense and, later, space. Beginning in the 1960's, steadily increasing levels of funding have been directed at what is generally called "civilian" R&D--that is, research and development where government itself is not the direct user but rather the results are to be applied to deal with general social and economic problems such as energy, environment, health and transportation.

³⁶ W. Overmeer and F. Prakbe, Government Procurement Policies and Industrial Innovation, Netherlands Organization for Applied Scientific Research, November 1978, p. 60 (reproduced by NTIS).

³⁷ See, e.g., OTA, op. cit., p. 37.

Effective Management of R&D

There are inherent difficulties in the effective management of government funding where the government is not the direct user. Since the actual users are generally not involved in the R&D, the work tends to lack definition. Often there is little or no concern about its actual application. As a result, the work may be ineffective or altogether inappropriate (as, for example, developing an exotic and expensive technology that is not competitive in the market). This leads to what has been called "implementation failure."³⁸

Several studies have considered this issue. A 1976 Arthur D. Little report concluded that "federally funded civilian research and development is not sufficient--by its self--to bring about technological change in the private sector to any significant extent."³⁹ It suggested that government incentives (including direct funding) are not the precipitators of innovation, but at best, are "additive"--perhaps providing a needed boost to the process. Based on a number of case studies, the study identified six elements which it said must converge for technological innovation to occur:

- knowledge generated through R&D
- user need
- an advocate or champion
- availability of resources
- favorable risk factors
- favorable timing

³⁸Peter W. House and D.W. Jones, Getting It Off the Shelf: A Methodology for Implementing Federal Research, Boulder: Westview Press, 1977.

³⁹Michael Michaelis, Ed., Federal Funding of Civilian Research and Development, Boulder: Westview Press, 1976.

Federal funding policies, in combination with other government incentives and requirements, can greatly influence this process but cannot control it entirely.

A 1977 study by House and Jones concerned itself with weaknesses in federal research management that have resulted in little of this research achieving commercial use.⁴⁰ They conclude that "implementation concerns. . . should drive the overall R&D process, rather than be viewed as the final stage or last event in the development of a technology" and suggest the use of a "Technology Implementation Plan" at the program level to achieve this objective.⁴¹

A Rand Corporation study analyzed the effectiveness of 24 federally funded demonstration projects and identified the following specific characteristics associated with those that were successful:

1. A technology well in hand. Projects showing significant diffusion success were those in which the principal technological problems had been worked out beforehand.
2. Cost and risk sharing with local participants. The cases showing significant diffusion success involved nonfederal cost sharing while those funded entirely by the federal government resulted in little or no diffusion.
3. Project initiative from nonfederal sources. Demonstration projects originating from private firms or local public agencies enjoyed greater diffusion success than did those directly pushed by the federal government.
4. The existence of a strong industrial system for commercialization. Diffusion proceeded more rapidly when there were obvious manufacturers and purchasers of the new technology, and when markets for similar products existed.

⁴⁰Op. cit.

⁴¹Id. at p. xiv.

5. Inclusion of all elements needed for commercialization. Demonstrations showing significant diffusion success included in their project planning and operations potential manufacturers, potential purchasers, regulators, and other target audiences.
6. Absence of tight time constraints. Demonstrations facing externally imposed time constraints fared less well than did the others.⁴²

Based on these findings, the report then went on to suggest a number of guidelines that federal agencies involved in demonstration projects could follow to increase the likelihood of success in future projects.

Similarly, a 1978 study by SRI International analyzed federal agency management practices for a large number of civilian R&D projects and correlated these practices with the commercial outcomes of the projects.⁴³ Based on this analysis, 36 operational guidelines are presented and discussed. They are grouped under three general headings: market planning and analysis; market intelligence and communication techniques; and selection and management of R&D performers. The first group of guidelines is directed towards having the agency understand and analyze the market during the planning phases of R&D. The second group of guidelines concerns the need for effective communications with and information gathering from participants in the R&D delivery system (including R&D performers and potential buyers and users). The third group primarily concerns the choice of and relationship with the R&D performer.

⁴²Walter S. Baer, L.L. Johnson, E.W. Merrow, Analysis of Federally Funded Demonstration Projects: Final Report, Santa Monica: Rand, April 1976.

⁴³Norman B. McEachron, H.S. Havitz, D.S. Green, J.D. Logsdon, and E. Milbergs, Management of Federal R&D for Commercialization, Menlo Park: SRI International, Sept. 1978.

Current R&D Policy

The Reagan Administration has undertaken a fundamental reassessment of the federal role in research and development. Although its policies are not yet fully articulated, it is clear that federal support in many areas of R&D is being reduced. In general, work with direct commercial application is being deemphasized and private industry is being encouraged to pick up the slack in this area. R&D required to meet regulatory objectives is still being supported, though at somewhat reduced levels. Traditional areas of government support since World War II, such as defense and nuclear energy, are receiving increased assistance.

Conclusion

While the government is in a position to greatly influence technological change through its direct support of R&D activities and procurement of technology-based products, federal support is being curtailed in some areas. In addition to these problems, many attempts to transfer technologies developed to civilian use have resulted in cases of implementation failure and have not been successful.

Organizational Conflict of Interest

When government agencies contract with private organizations for the provision of materials or for R&D services, potential conflict of interest is an important issue. One definition of organizational conflict of interest, originally developed by the Atomic Energy Commission, is

. . . A situation where a contractor, normally a corporation, has interests, either due to its other activities or its relationships with other organizations, which place it in a position that may be unsatisfactory or unfavorable (a) from the government's standpoint in being able to secure impartial, technically sound, objective assistance and advice from the contractor, or in securing the advantages of adequate competition in its procurement; or (b) from industry's standpoint in that unfair competitive advantage may accrue to the contractor in question.

Two types of potential conflicts arise from this definition--those affecting government objectives and those affecting private sector objectives. Government agencies have an interest in assuring that no improper influence or unfair advantage is used to affect the selection process in contracting with outside organizations. Government agencies also want to assure that the outside contractor does not have adverse or competitive interests that might negatively influence the matter under contract. The private sector, in turn, is concerned that government not unduly favor certain organizations and, through public funds and support, unfairly affect private competition.

Potential Conflict of Interest in the Selection Process

The main issues here involve situations where key agency personnel have close relationships with organizations seeking contracts (as, for example, may exist if former government employees now work for these private organizations and vice versa) and where private organizations have assisted in preparing the request for the contract arrangement. In each of these situations, questions regarding conflict of interest may be raised.

During the Carter Administration, the issue of the "revolving" door between government and industry was widely discussed. One result was passage of the Ethics in Government Act of 1978 (Public Law 95-521). Title V of the Act places restrictions on the employment activities of

all former federal employees in order to avoid conflict of interest situations. For example, senior government employees who leave their positions cannot, for a two-year period, assist an organization involved in any formal or informal appearance before their former agency. One effect of this law is to discourage government service by well-qualified industry personnel.⁴⁴

The old Energy Research and Development Administration (ERDA) had a regulation pertaining to this concern:

A contractor's judgment may be biased because of past or present relationships of its officers or employees with other organizations and because of organizational relationships (e.g., interlocking directorships). In selecting a contractor to develop technical specifications in connection with competitive procurement or to perform evaluation services on technical proposals, consideration should be given to present and past relationships of the contractor's organization and personnel to the companies whose proposals are to be evaluated. In order to avoid or minimize organizational conflicts of interest and to avoid assignments of work which would create unavoidable conflicts of interest, these relationships may require that an organization be eliminated from consideration for selection, or that a reasonable period of restraint, for example, 1 year, be imposed on the organization or on the use of certain employees in the performance of contract work.

Regarding outside assistance in preparing contract requests, the Office of Management and Budget proposed the following restrictions in the awarding of grants:

In order to insure objective contractor performance and eliminate unfair competitive advantage, a contractor that develops or drafts specifications, requirements, a statement of work, or invitations for bids and/or a request for proposals for a particular procurement shall be excluded from competing for and performing work under the

⁴⁴See, e.g., "Interest conflict laws need revamp for U.S. to tap industry experts," Oil and Gas Journal, Vol. 79, April 20, 1981, p. 25.

directly ensuing procurement except when the grantor agency gives approval to a grantee's request to⁴⁵ waive this requirement for a particular procurement.

NASA has a regulation that restricts on-site support service contractors who prepare specifications or statements of work from competing for contracts which incorporate such specifications or statements for three years.⁴⁶ The Department of Defense has similar provisions in its contracting regulations.⁴⁷

Conflict of Interest in Performance of the Contract

The government's interest in obtaining "impartial, technically sound, objective assistance" may be promoted by requiring all potential contractors to disclose information bearing on potential conflicts of interest. For example, the Department of Energy requires in certain circumstances that the submitter of a contract offer include a statement that describes "all relevant facts concerning any present or planned interest (financial, contractual, organized, or otherwise) relating to the work to be performed hereunder and bearing on whether the offeror has a possible conflict of interest. . ."⁴⁸

Much of the interest in this issue arose as a result of a contract award by the Office of Coal Research (then in the Department of the Interior) on a sole-source basis to Bechtel Corporation for a study of coal slurry pipelines. At that time, Bechtel had a 40 percent interest

⁴⁵Federal Contracts Report, No. 671, March 7, 1977, Appendix D, Draft of Proposed Changes to Attachment O, Procurement Standards, FMC 74-7.

⁴⁶ASPR, Appendix G.

⁴⁷NPR 1.113-2(b).

⁴⁸Regulation 9-1.5405 and 9-1.5406. This disclosure requirement only applies to evaluation, technical consulting and management support services. It does not apply to contracts for research and development or architect-engineering services.

in Energy Transportation Systems, Inc. (ETSI), the proponent of a major coal slurry pipeline from Wyoming to the southeastern U.S. Senate hearings were held concerning this contract award in 1975. During these hearings, Senator Abourezk argued the position that "a conflict may exist wherever a contractor may receive benefits from the contract beyond those specified in the contract."

In addition to conflicts that may exist before entering into a contract, there is also the concern about conflicts that could arise because of later developments. Thus, for example, the Nuclear Regulatory Commission prohibits a contractor, during the term of the contract, from entering into any contract with others if such other contract may give rise to an actual or potential conflict of interest.⁴⁹

Unfair Competitive Advantage From Contract

The performance of a government contract necessarily benefits the private performer. Under most contracts, materials or services are being purchased. Salaries and organization overhead are paid. Fees may be paid and direct profits earned. In the case of research and development contracts, the fund of information available to the private R&D performer is purposely increased at government expense. In general, these advantages are a necessary and desirable part of the process.

However, there are certain aspects of this process that have drawn attention as allowing unfair advantages to contractors. One situation is where the contractor receives the proprietary data of other companies in the course of its work. The Department of Defense regulations provide that

⁴⁹43 Fed. Reg. 3288, Jan. 24, 1979.

if a contractor agrees to conduct studies or provide advice concerning a system, which work requires access to proprietary data of other companies, the contractor must agree with such companies to protect such data from unauthorized use or disclosure so long as it remains proprietary.⁵⁰

NASA also has a regulation requiring its contractors to protect the proprietary data of others obtained under the contract and not to utilize such data to compete with its owners.⁵¹

A more difficult situation involves the case where a private organization has performed substantial development work under government contract and the government then desires to purchase quantities of the resulting product. One response to this problem has been the establishment of government sponsored nonprofit corporations to perform the conceptual design, analytical studies, systems engineering and technical directions. Private firms providing these services have often been subjected to so-called "hardware exclusion clauses" under which they are barred from seeking the subsequent follow-on production contracts.⁵² At the same time, DOD regulations note that

in development work it is normal to select firms which have done the most advanced work in their field. Even though contractors may have performed such development work on a DOD contract and have an unavoidable competitive edge in contracts for the items developed, this advantage is not to be considered unfair and no prohibitions on follow-on work should be imposed.⁵³

⁵⁰ASPR, Appendix G.

⁵¹NPR q.113-2 (b).

⁵²Leonard Rawicz, "Organizational and Individual Conflicts of Interest-- Impact of the Roles on Contracting," Briefing Conference on Government Contracts, March 13 & 14, 1978, Philadelphia, Pennsylvania, p. 138.

⁵³Id. p. 141.

Conclusion

There is no uniform government policy regarding organizational conflict of interest. Some government agencies have no published regulations dealing with organizational conflict of interest.⁵⁴ Others have rather limited treatment of this subject, often developed in response to specific issues rather than based on a full consideration of the issue. Most Congressional attention to this issue has been in relation to specific agencies. In some respects, this approach is appropriate. The definition of conflict of interest may well depend on the mission or responsibilities of the government entity. A regulatory agency such as the Nuclear Regulatory Commission may require one set of standards while a more broad-based entity such as the Department of Defense may need something quite different. It also seems desirable to allow agencies to develop their own procedures for identifying and evaluating potential conflicts of interest.

At the same time, this area of organizational conflict of interest is inherently fuzzy. The interrelationships of government and industry are always the subject of suspicion by some. The General Accounting Office stated in a 1980 report that it found potential conflict of interest situations in 101 of the 156 contracts that it sampled at 6 government agencies.⁵⁵ A flagrant case of abuse of the discretion available to government agencies in this area could result in legislation that is overreactive and unduly restrictive. Indeed, with respect to the Ethics in Government Act, that may already be the case.

⁵⁴For example, the Department of the Interior has only an internal procurement bulletin. The General Accounting Office Study, referenced above, also found that the Consumer Products Safety Commission had no conflict of interest regulation.

⁵⁵Lloyd Schwartz, "Regulatory Analysis Pacts Cited in Conflict-of-Interest Probe," Electronic News, V. 26, Supplement pp, May 12, 1980.

The Freedom of Information Act

When the Freedom of Information Act (FOIA) was first passed in 1966, it was done so in the context of two decades of greatly increasing government activity. Internal documentation of this activity was generally treated as confidential irrespective of the information involved. The basic intention of the FOIA was to open up the workings of government--to make available information on what government agencies were doing.

Congress did recognize that not all government-held information should be available. The Act specifies nine areas in which disclosure requirements may be exempt. Included are matters that are:

1. Specifically authorized and properly classified as secret in the interest of national defense or foreign policy;
2. Related solely to the internal personnel rules and practices of an agency;
3. Specifically exempted from disclosure by statute;
4. Trade secrets and commercial or financial information obtained from a person and privileged or confidential;
5. Inter-agency or extra-agency memoranda or letters not otherwise available by law except to an agency in litigation with the agency;
6. Personnel, medical, and similar files whose disclosure would constitute an invasion of privacy;
7. Under some circumstances, investigatory records compiled for law enforcement purposes;
8. Records related to the regulation or supervision of financial institutions;
9. Geological and physical information and data, including maps, concerning wells.

Although this matter is not totally settled, most courts have ruled that these exemptions are discretionary. Even if the material requested could be considered to fall within one of the exemption categories, the agency could still determine that it is in the public interest to release the information.

In 1974, the FOIA was amended to require that agencies either grant or deny an FOIA request within ten working days, though there is no specified time within which the material must be made available if the request is granted. While the agencies can charge for the search time and for copying materials, they cannot charge for their review time. In practice, the fees charged tend to be minimal.

Disclosure of Business Information

One unforeseen consequence of the Act is the degree to which it is used to gain information about businesses. It has been estimated that about two-thirds of the requests for information under the FOIA come from industry or its representatives.⁵⁶ As government has expanded the scope of its involvement with industry, substantial amounts of business information have passed to government. While the fourth exemption listed above was intended to protect "trade secrets" and treat commercial or financial information as "privileged or confidential," this exemption was construed narrowly in a 1974 decision that has been followed by other courts. The Circuit Court for the District of Columbia concluded in the so-called National Parks I case that

⁵⁶ Richard A. Mann, "Industrial Espionage Made Legal: The Freedom of Information Act," University of Michigan Business Review, 31:13-17 (Nov. 1979), p. 13.

commercial or financial matter is "confidential" for purposes of the exemption if disclosure of the information is likely to have either of the following effects: (1) to impair the government's ability to obtain necessary information in the future; or (2) to cause substantial harm to the competitive position of the person from which the information was obtained.⁵⁷

Thus, the exemption is only to apply where disclosure can be shown to cause substantial competitive harm. It has been argued that this is a major alteration in the intent of Congress. Nevertheless, other courts have followed this approach.

A Freedom of Information request is made, of course, to a government agency. However, the government agency is poorly equipped to evaluate the competitive effect of releasing business information. In most cases, the affected party is the business--not the government agency. Yet there is no requirement that the business be contacted before information is disclosed. One result has been an increasing number of "reverse-FOIA" suits brought by the submitters of information to prevent an agency from disclosing that information. Even when an agency does contact the submitter regarding an FOIA request, it is no easy matter to show substantial competitive harm within the ten-working-day requirement.

Some Examples

The consequences of disclosure can be significant. In one prominent example, a company had designed a 42-person inflatable life raft and had submitted its design and testing data to the Federal Aviation Administration for approval which it received. Shortly thereafter, a competitor used the FOIA to obtain portions of this information which it used to

⁵⁷ National Parks & Conservation Association v. Morton, 498 F.2d 765 (D.C. Cir. 1974).

design its own comparable raft. The competitor then won a substantial contract for the sale of these rafts.⁵⁸

Another example involved a technology developed by Dow Chemical to detect and reduce a hazardous impurity (bio-chloromethyl ether) in a commercial process.⁵⁹ Personnel from the National Institute of Occupational Safety and Health (NIOSH) had visited a Dow plant to obtain information regarding this matter and wrote up a report of their findings. A representative from Mitsubishi Chemicals learned of this report in a meeting with NIOSH personnel. He requested and received a copy. Mitsubishi had been negotiating with Dow to license this technology.

In a recent example, the Environmental Protection Agency inadvertently disclosed the secret formula of Monsanto Company's widely used agricultural herbicide, Roundup, in response to an FOIA request by a Washington, D.C., lawyer.⁶⁰ Although the ultimate recipient of the information is not known for certain, it is thought that it went to a rival company. At the present time, the Monsanto product holds a dominant position in this market.

Agency Difference

Because there is no requirement for uniformity, the approaches among the agencies differ substantially. Some agencies have policies that favor disclosure. For example, the Consumer Product Safety Commission requires

⁵⁸ B. Schors, "How Law is Being Used to Pry Secrets from Uncle Sam's Files," Wall Street Journal, May 9, 1977, p. 1.

⁵⁹ Attachment V to Written Statement, Jack I. Palley, Attorney, Dow Corning Co., Freedom of Information Act Oversight, Hearings, Committee on Government Operations, July 14, 15 and 16, 1981, at p. 553.

⁶⁰ Washington Post, Sept. 18, 1982, p. 1.

a submitter of information who seeks confidential treatment under exemption four to accompany the submission with a specific request for confidentiality, to identify the confidential portions, to state whether the information has ever been released to a nonemployee, to state whether the information is commonly known or readily ascertainable by outside persons, to state how release of the information would be likely to cause substantial competitive harm, and to state whether the submitter is authorized to claim confidentiality on behalf of the organizations involved. The Commission does not determine whether an exemption applies until an FOIA request is received.⁶¹

Others tend to provide more protection for business information. For example, the Food and Drug Administration (FDA) developed its own internal procedures for defining the kind of information that should fall within the fourth exemption. It reviewed its files and categorized the kinds of information it found there in order to develop a consistent and comprehensible approach to disclosure. Where information requested under the FOIA is found to fall within the definition of the fourth exemption, FDA will not release that information.

The attitudes and approaches of the agencies are often a reflection of their missions. The Consumer Products Safety Commission is an outcome of the consumer movement of the 1970s. The FDA has been around in some form for most of this century and has developed long-term working relationships with the businesses it regulates. While the variability in treatment creates uncertainties for business, it also allows an agency to establish the approach that seems best suited to its activities and functions. Subject

⁶¹Kevin R. McCarthy and John W. Kornmeier, "Maintaining the Confidentiality of Confidential Business Information Submitted to the Federal Government," The Business Lawyer, 36:57-78 (Nov. 1980), p. 74.

to judicial review, agencies can adopt procedures that will provide the fullest possible opportunity for companies that submit information to demonstrate the need for confidential treatment.

Proposed Changes

There has been some movement since the Reagan Administration took office to change the FOIA. William French Smith, Reagan's Attorney General, rescinded the guidelines established under the Carter Administration that had urged nondisclosure only where "demonstrably harmful." Several bills have been introduced in Congress in the past two sessions that would tighten the standards and procedures for disclosing business information. For example, it is proposed to change the standard for non-disclosure from whether the submitter would be substantially harmed to simply whether the submitter would be harmed. Other likely changes include extending the time agencies have to make decisions on FOIA requests, requiring notification of the submitters when an FOIA request involves its information, and allowing agencies to increase fees charged of those making an FOIA request.

Conclusion

The Freedom of Information Act may well have a chilling effect on the willingness of a company to voluntarily submit information to a government entity and thus may hinder public/private cooperative efforts. Certainly at this point, companies know that they must take steps to protect their information by requesting confidentiality. If the agency has a procedure that is supportive of this need for confidentiality, the burden on the company may not be too substantial. Nevertheless, the company must always be prepared for possible court review of an FOIA denial by an agency. The existing review standard of "substantial competitive harm" is not an easy

one to meet. Reverse-FOIA suits have not succeeded in clearing up the problems. It is clear that changes are needed to eliminate this unnecessary problem.

Summary and Conclusion

In summary, federal tax provisions are generally a favorable influence on the development of technology and innovation. Specifically, non-capital R&D expenditures are given favorable treatment. Capital investment generally has been encouraged through investment tax credits and accelerated depreciation. Start-ups of new businesses, especially those oriented toward investing in "high tech" opportunities, have been favored with tax incentives. Other improvements have been proposed and may be warranted. On balance, however, the tax structure cannot be considered an impediment to innovative activity.

The patent system has been improved in several ways during recent years. Government policy with respect to rights to inventions arising out of federally funded research and development has been clarified. Nevertheless, there are indications that the system is not able to keep pace with the rate of new inventions, that it is unnecessarily costly, complicated, and often insecure, and that, as a result, it is not being used in many cases. Again, while improvements are clearly warranted, it is doubtful if the problems with this system have a significant effect on technological development.

Antitrust laws appear to have mixed effects. Antitrust enforcement is intended to promote competition and competition encourages innovation. However, enforcement that penalizes successful innovation behavior as in the du Pont case tends to counteract other positive effects. Treatment of joint R&D ventures by the Justice Department now appears more favorable, opening the way to increased use of this cooperative approach.

Regulatory effects are varied and difficult to categorize. On the one hand, regulation can be used to promote innovation and technological development in areas where normal market incentives do not. On the other hand, regulation may inhibit other innovation by diverting resources or restricting certain types of activities. Most of the U.S. regulatory schemes appear to have been developed with little or no regard for their effect on innovation and perhaps not enough consideration of their effects on the U.S. economy in general.

Federal procurement of technologically-oriented goods has been successful in several important instances in promoting more rapid development of technology. Federal support of R&D, especially for civilian application, has been less successful. The purpose of procurement, however, is to acquire the needed product. Broader innovation benefits are incidental. Efforts to transfer usable innovations are not well organized and supported and the results have been uneven. Moreover, federal support for R&D is being cut back in certain areas, especially for work with commercial application.

Potential conflict of interest must be considered in any contractual arrangement between government and a private firm. A variety of issues are involved including such things as improper influence in the selection process, conflicting objectives in the contract performance, and unfair competitive advantages arising out of the contract performance. As the Bechtel contract with the Office of Coal Research illustrated, the government's interest in obtaining highly qualified assistance can raise questions about the benefits that may result. These are difficult judgments not readily susceptible to absolute rules and standards. Attempts to establish such standards such as with the Ethics in Government Act may be unnecessarily restrictive. However, uncertainty regarding conflict of interest may well hinder some public/private interaction.

The Freedom of Information Act presents another potential impediment to public/private interaction. The possibility that confidential business information given to the government could be made public under an FOIA request undoubtedly inhibits a willingness to share information. Although there are relatively few significant instances of important confidential information being released through the FOIA, these occurrences have received considerable publicity. Some improvements have been made but others are needed to remedy the situation.

This review of selected government policies demonstrates that the general underlying intention is to encourage innovation. In some instances, this intention is quite explicit as in the case of the patent law. In other instances, such as the tax provisions encouraging capital investment, innovation is an indirect but important beneficiary.

Furthermore, where specific impediments to innovations caused by existing policies have been identified and agreed upon, a number of changes have been made. Examples here include the change in patent laws allowing universities and small businesses to be able to patent inventions made during any federally funded research and the development by the Justice Department of a Guide regarding joint R&D ventures. In addition, some policies favoring innovation have been improved and expanded. A prominent example is the expanded tax benefits allowed for R&D expenses in 1981.

On the other hand, this review also illustrates the absence of a clear, explicit policy regarding innovation. Indeed, the role of the federal government in the innovation process seems to be in flux at present. Direct federal funding for civilian R&D is being cut back after 15 years of continuous, substantial growth. Thus, at least with respect to this approach to encouraging innovation, it appears that the federal government is reducing its active involvement in the innovation process.

An important corollary to this approach, however, is the requirement to actively eliminate impediments to desired private activity. If the U.S. government is moving in the direction of less active involvement in the innovation process, then it must assure that private sector opportunities are not unnecessarily inhibited by other federal policies.

This raises some difficult issues. For example, antitrust policy is well established. In their general outline, its objectives are probably favored by most Americans. Yet, in its application, it appears to discourage cooperation between companies and may even discourage being too successful.

Similarly, many of the objectives being sought through environmental, health, and safety regulation are widely desired. However, the "command and control" approaches that have been adopted are costly and appear, on balance, to limit rather than encourage innovation. Yet, judging from the legislative debate in the past two years regarding amending the Clean Air Act, major changes in U.S. regulatory structure are not likely.

Innovation activity in the U.S. economy as measured by such indicators as patent applications and productivity improvements has been lagging in recent years. However, it should be noted that productivity has been lagging in other countries as well during this same period. The government policies reviewed in this paper are only one part of many factors at work in the innovation process. In general, the policies reviewed here tend to favor innovation or at least do not significantly impede it. Certainly, many improvements are possible and would be desirable. However, in the absence of a coherent policy that would clarify and give directions to the federal role in innovation, such incremental changes are not likely to have a significant effect.

APPENDIX F

Lessons From the Technology Transfer Experiences
of Non-NASA Federal Departments and Agencies

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LESSONS FROM THE TECHNOLOGY TRANSFER EXPERIENCES
OF NON-NASA FEDERAL DEPARTMENTS AND AGENCIES

Introduction

Because of its high technology focus and well publicized efforts in the area of technology transfer, NASA is the federal agency most commonly associated with the field of technology transfer. In fact, however, many other departments and agencies of the federal government have also been directly or indirectly involved in the effort to transfer the results of federal R&D to other sectors of the economy.

The history of federal attempts to promote technology transfer is a checkered one. Agency efforts typically have been characterized by poorly defined (and often conflicting) mandates, sporadic commitment, irregular funding, and experimentation with a variety of organizational structures and transfer mechanisms. Few federal agencies have been able to maintain a continuous commitment or program over the years. The experiences of individual federal agencies seem to vary according to the nature of the agency mission, the strength of its technology focus, the interest and commitment of senior management and staff, and the nature of (and its relationship to) client groups and potential technology users.

At the present time, federal technology transfer efforts are once again in a state of flux. On the one hand, the Stevenson-Wydler Technology Innovation Act of 1980 provides federal agencies with a clear mandate to actively pursue technology transfer activities. At the same time, however, these agencies must also respond to the demands of the current administration. Budget cuts, restrictions on printing and information dissemination, structural reorganizations and a general shift in the priorities and objectives of the executive branch may limit the ability of federal agencies to respond to this mandate.

In light of the current situation, two points seem clear:

1. Because of resource limitations, future federal efforts in the technology transfer area must be more carefully focused (i.e., concentrate on maximizing results relative to the amount of resources committed).

2. A re-examination of past and current approaches to federal technology transfer is required. What lessons do the experiences of federal agencies provide that might help today's program managers structure their programs and allocate their resources most effectively?

Any attempt to draw conclusions from the past experiences of federal agencies in the technology transfer field is fraught with danger. The range of experiences is quite varied. A number of agency programs have been short-lived, and many have suffered from inadequate funding and staffing. Still others have achieved successes due largely to the nature of the technology being transferred, the characteristics of the client group, the efforts of a few highly motivated individuals, or some other unique factor or situation which is unlikely to be duplicated in other applications. Despite these limitations, the collective experiences of federal agencies do represent an important source of information. A review of these experiences reveals a number of common themes or "lessons." These lessons are summarized in capsule form below:

1. The Need to Institutionalize Technology Transfer Activities--Few agencies have succeeded in incorporating technology transfer activities into their basic mission and basic programs. In most cases, if technology transfer activities have been pursued at all, they have been pursued as an adjunct or related activity. Transfer activities need to be integrated with routine functions (preparation of job descriptions, creation of a reward system, budget preparation, program goal setting, etc.). Separate isolated technology transfer structures have tended to be short-lived and often have had limited impact. In agencies where transfer activities have been viewed as a distraction to pursuit of the agency mission, they have typically been among the first activities curtailed or eliminated for budgetary reasons. In addition, a large portion of agency activities that could potentially constitute technology transfer (such as procurement, contracting, regulation, etc.) fall outside of and are often unrelated to specifically identified agency transfer programs.

2. The Nature of the Client Group and Potential Users--Agency successes in the technology transfer field appear to have been greatly influenced by the characteristics of client groups and potential users, and the nature of their relationship with these groups. For example, the Department of Agriculture (USDA) has been quite successful in transferring agricultural technology to the U.S. farm community. This success can be attributed in part to the nature of the client group--i.e., fragmented, engaged in atomistic rather than rivalrous competition, visible and well organized, plays a large role in setting agency research priorities, generally educated and prone to experiment with new technology, etc.¹ In addition, USDA (through its highly decentralized system of county agents) has developed a close working relationship with these potential users of new technology. The same high degree of success would not be possible with a less cohesive, less well defined client group in which members engaged in more direct competition with one another. Obviously the degree of difficulty increases when the potential users of technology are not a part of or related to the agency's traditional client group(s).

3. Transfer Mechanisms--Agency technology transfer programs have experimented with a number of different transfer mechanisms over the years. Traditional mechanisms such as reports, articles for technical journals, cataloguing systems, workshops and symposia have been most widely used. Not surprisingly, it is not possible to generalize as to which mechanism is "best" or even preferable to another. The effectiveness of each depends on the particular situation. However, it does appear that the more passive mechanisms (basic information collection and dissemination through traditional sources), while important, can play only a limited role. More active mechanisms (where person-to-person contact is more likely to take place) appear to hold greater potential to increase the flow of technology.

4. The Importance of Networks and Personal Contact--Federal agency experiences highlight the value of creating networks and increasing personal contact. Proximity to and regular interaction with potential users of federal technology appear to have been important elements in a number of successful transfer efforts. Although there are exceptions, de-centralized structures (capable of promoting this type of interaction) appear to have worked better than highly centralized structures. While the evidence is limited, past experiences also seem to indicate that substantial benefits can result from joint participation projects in which the generators and potential users of technology work together.

5. Political and Social Support--Past experiences clearly indicate the need for widespread political and social support for federal transfer activities in order for them to 1) succeed in achieving their objectives and 2) continue to receive agency support and funding over the long run. Few agency technology transfer efforts have enjoyed this type of political and social support.

6. The Federal Role in R&D Support--Federal support of R&D appears to have been most effective and least controversial when strengthening the infrastructure of science and technology (i.e., through education, training, basic research, etc.).² In general, the level of complexity and controversy encountered has increased when federal support is applied to specific missions and specific industries--where economic and market factors must be considered.

7. The Characteristics of Successful Transfer Experiences--Presented below is a list of some of the characteristics generally associated with successful transfers of technology. No single transfer had all of these characteristics, and many undoubtedly succeeded for reasons other than those presented here. The following list simply indicates those factors which more often than not have been present in successful federal transfer experiences:

- users had ready access to the necessary information
- a market existed for the technology application
- transfer did not directly disrupt existing social systems
- support requirements (i.e., the user's technical capabilities, facilities, resources, etc.) were not excessive
- advocates of transfer were trusted sources of information
- a limited number of individual approvals were required to adopt the technology
- the adopted technology did not replace a standardized item where the costs of change-over were high (unless the benefits far exceeded the cost)
- adoption required incremental rather than wholesale change
- adoption did not dramatically change the relationship between suppliers and customers
- the federal government supported adoption (through technical assistance, loans, etc.)
- the federal government subsidized the market (particularly where the federal government was itself a customer--e.g., aircraft, electronics, etc.)

8. The Nature and Focus of the Agency Mission--In the past, the more specialized the agency mission (and the more divorced that mission from the needs of the general economy), the less likely the agency would be to find and diffuse technology to the general economy. For example, much of the work performed by the Department of Defense (DOD) and the nuclear weapons portion of the old Atomic Energy Commission (AEC) focused on very specific economic sectors. The technologies developed by these agencies tended to be costly, risky, inapplicable or inaccessible. These experiences can be contrasted with those of agencies such as the USDA, the Department of Energy (commercial nuclear and non-nuclear components), the Small Business Administration (SBA) and the Department of Commerce's Minority Business Development Agency (MBDA - formerly the Office of Minority Business Enterprise).

Recent efforts by DOD and others to increase their role in technology transfer appear to have reduced, although not eliminated, the importance of the agency mission as a factor in the transfer process. A specialized agency mission with limited connection to the general economy need not present a permanent obstacle to effective technology transfer.

9. Opportunities to Expand the Agency Role--Past experiences indicate that more can be done to promote:

- inter-agency cooperation (particularly cooperative efforts between technology generators like DOD and agencies with established networks among potential users, like SBA),
- agency/private sector cooperation (an increased emphasis on transfer through joint participation),

- the use of more potential channels for technology transfer (including federal procurement of hardware and services, development work, etc).

The Experiences of Individual Federal Departments and Agencies

The technology transfer experiences of federal agencies are as varied as the agencies themselves. Each has had its own unique history and particular approach to the diffusion of technical information. Because of this variety, it is simply not possible to discuss these experiences collectively. Instead, a brief description and discussion of the experiences of a sample of federal agencies is provided below.

The Federal Laboratory Consortium (FLC) for Technology Transfer. The FLC was begun informally in 1970 at the Naval Weapons Center at China Lake, California. The FLC, known then as the Defense Technology Transfer Laboratory Consortium, consisted of eleven DOD laboratories. By 1974, when all federal laboratories were invited to participate, the FLC had 34 members. Today, the FLC has over 200 federal laboratories and centers (representing eleven federal agencies) as participating members.³ Defense, Forest Service and Fish and Wildlife facilities make up over 80 percent of the total membership.

The FLC is currently organized into six geographic regions. Each region is represented by a regional coordinator. Each member facility has a designated technology transfer representative. Together, these representatives form a substantial national network. In addition, the FLC has identified ten technical specialists who provide support in specialized fields on individual requests for assistance and special projects.

The primary goal of the FLC is to facilitate the effective use of federal technology and expertise in addressing domestic needs in the public and private sectors by providing the environment, the operational structure, and the necessary transfer mechanisms. The FLC seeks to do this by

eliminating barriers to the flow of technical information and promoting person-to-person communication between the resource people in federal laboratories and potential technology users.

From its beginnings as an ad hoc affiliation of a handful of DOD laboratories, the FLC has slowly evolved into a larger, more mature organization. At present, the FLC represents one of the more active technology transfer efforts within the federal government. Despite minimal funding and varying levels of commitment from the agencies represented, the FLC has achieved some degree of success. A large part of its efforts have been directed at state and local governments. FLC members have provided assistance to a number of state and local governments on a "consulting" basis. In addition to this type of ad hoc problem solving, the FLC also entered into a pilot project with the U.S. Conference of Mayors. The project, known as the Community Technology Initiatives Program (CTIP), linked federal laboratory resources with 32 small local governments through the use of circuit riding technology agents. In 1981, the U.S. Conference of Mayors estimated that the program had already saved local governments over \$2.6 million. The FLC has also established cooperative efforts with the National Association of Counties, the National Conference of State Legislatures, and other public organizations.

In addition to its work with state and local governments, the FLC has also attempted to develop similar linkages with private industry. These efforts have included a demonstration program with the Santa Clara Chamber of Commerce in California, a technology showcase for private industry in New Mexico, and a series of business opportunities conferences. Each of these activities has been designed to familiarize private industry with the types of technologies and resources available in federal laboratories.

Although it is potentially an important contributor in the technology transfer field, the FLC suffers from a number of limitations. It has been more than ten years since the Consortium was established, yet it still lacks a reliable funding source and still has not obtained a high level of commitment from the agencies involved (despite the provisions of the Stevenson-Wydler Technology Innovation Act).⁴ The level of participation and interest appears to vary greatly from one laboratory to another. The continued operation of the FLC still appears to be dependent on the involvement of a relatively small number of highly motivated individuals within the federal laboratory community (as it has been from the start).

The FLC appears to have been most effective in its role as a consultant/ problem solver for local and state governments. It has also succeeded in establishing a national network of resource people and creating opportunities for personal contact between these people and potential technology users. However, the FLC has yet to move much beyond this consultant role and has yet to establish an effective link with private industry. As a result, much of the available technology in the member federal laboratories is still not reaching the industrial users who might potentially benefit the most from it.

The Department of Defense (DOD). Of all the federal departments and agencies, DOD's expenditures for research and development are by far the largest. As a result, DOD is the largest generator of new technology within the federal government. DOD's experiences in the technology transfer field have evolved over the years, and have been greatly influenced by the nature of the Department and its mission.

For many years, DOD made no special effort to transfer the technology it supported and developed. Some elements were in fact successfully transferred (jet aircraft, helicopters, electronics, etc.), but not as the result of a conscious effort or program. DOD is highly mission-oriented, and the national security objectives of that mission have encouraged the agency to classify and limit access to information rather than disseminate it. In the past, DOD has been criticized for failing to make technical information available even to its own contractors.

DOD R&D operations are substantially different from those of other federal agencies. DOD places a great deal of emphasis on predevelopment technical definition. Innovation and technical development within DOD is highly centralized. The adoption or rejection of technology is typically decided before applied research and development are completed.⁵ Internal client needs are known to a much greater extent than is true for most federal agency programs. DOD's centralized approach to technology transfer largely reflects these characteristics. DOD transfers technology to the general economy mainly by relinquishing patent rights to its prime contractors (while maintaining a free license for the government). Little effort is made to evaluate information outside of the interest profiles of DOD and its prime contractors. DOD also affects the development and diffusion of technology by furnishing a market (through highly detailed specifications) for particular items and systems components.

In addition to these activities, DOD also engages in a variety of training and informing activities. These efforts, however, are directed almost entirely to the needs of service personnel and DOD contractors engaged in development work. DOD records technical information and reports generated by its R&D work in the Defense Technical Information Center.

Because much of this material is classified, however, access is generally limited to DOD personnel and prime contractors on a need-to-know basis. In addition, the Defense Logistics Agency also operates a number of Information Analysis Centers. These centers contain technical personnel capable of providing quick response analysis of specialized technical problems or issues.

Although there has been a growing awareness of the need to transfer some of the benefits of defense-related R&D to the general economy, DOD has not had (and still does not have) a particularly strong technology transfer policy. Prior to the mid-1960s, DOD made little formal effort to promote transfer. In 1967, DOD attempted to open up its contracting activities to new firms (thus allowing more private contractors to have exposure and access to DOD technology). In FY 1967, one in five of the top 500 defense contractors had not been on the list in FY 1966 (although the top recipients remained virtually unchanged). DOD's first formal effort to address the need for technology transfer came when then Secretary of Defense Melvin Laird established the Domestic Action Council "to secure benefits for the economy from DOD expenditures." Since that time, however, DOD has relied on its prime contractors as the main vehicle for achieving technology transfer. Many observers have questioned whether defense contractors actually produce products for commercial markets to any significant extent.⁶ Often the defense divisions and commercial divisions of large DOD contractors operate quite independently, providing little opportunity for a flow of people or technical information.

Each service branch within DOD has particular technological needs. As a result, their R&D activities and contributions have varied. So too have their efforts in the technology transfer field. By far, the Department

of Navy has been the most active service branch. The activities of the Army, Navy and Air Force are briefly summarized below.

Army:

Army efforts in the technology transfer field have been somewhat limited. Army regulation AR 70-57 endorses the concept of Army-civilian technology transfer, but little has been done to formalize this support. The bulk of the Army effort consists of the participation of 27 of its laboratories and testing centers in the Federal Laboratory Consortium. Several of these facilities have been quite active in FLC programs. In addition, the staff of the Office of Army Research attempts to maintain contact with a variety of institutions in order to transfer new information resulting from Army basic research.

Navy:

The U.S. Navy was the first service branch to issue an implementing instruction calling for an active technology transfer program. In 1972, the Navy instituted a formal Technology Transfer and Cooperative Development Program. This program was initially oriented towards support of federal agencies. In recent years, however, the Navy has broadened its focus in an attempt to serve the needs of state and local governments, small business, and industry as well. Navy personnel at the China Lake Weapons Center were also responsible for the formation of what has grown to become the Federal Laboratory Consortium (FLC).

The Chief of Naval Material has responsibility for the Navy-wide transfer program. An Assistant Deputy Chief of Naval Material serves as the Director of Military-Civilian Technology Transfer and Cooperative Development. The major components of the Navy technology transfer program include the following:

1. The Government Industry Data Exchange Program

The Navy manages this cooperative program, sponsored by DOD, other federal agencies and the Canadian Department of Defense. The program enables government and industry to supply information for and retrieve information from four specialized data banks covering systems and equipment reliability-maintainability, engineering, and failure experience. The program offers two unique services. The ALERT system notifies participants of particular problem areas, while the Urgent Data Request System allows members to query all participants on specific problems.

2. The Invention Licensing Program

The Office of Naval Research manages this program in cooperation with the Headquarters Naval Material Command. Patented Navy inventions are licensed to private industry and small business for commercial development. Beginning in 1977, the Office of Naval Research also began filing selective patent applications in foreign countries for inventions with high commercial potential.

3. The Federal Laboratory Consortium

Eighteen Navy facilities currently participate in FLC activities. A staff member of the Naval Weapons Center has served as Consortium Chairman since its inception. Naval personnel were particularly active in the FLC's Far West Region Local Government Assistance Task Force.

4. Intergovernmental Personnel Assignments

The Navy uses short-term intergovernmental personnel assignments to make Navy technical personnel available to federal agencies and state and local governments.

In addition, the Navy also attempts to promote joint Navy/industry research and development projects through the Navy Industry Cooperative Research and Development (NICRAD) program. ⁷

The transfer mechanisms employed by the Navy include :

- a network of transfer contacts involved in approximately 70 Navy activities
- the use of technical advisers to assist other federal agencies, state and local government, and industry
- publication of technical periodicals describing Navy inventions and technology (including the Navy Technology Transfer Fact Sheet, which is distributed each month to over 3,000 potential users in government and industry)

- sponsorship of or participation in a variety of conferences, seminars, symposia and exhibits
- publication and dissemination of numerous documents other than technical periodicals
- operation of information centers (including the Shock and Vibration Center's Direct Information Service, which provides rapid response to subscriber inquiries). Current Navy R&D work with potential civilian benefits is also identified in the Work Unit Information System Data Bank operated by the Defense Technical Information Center.

Air Force:

Air Force efforts continue to focus largely on the transfer of technology through its major contractors. Roughly three-quarters of all Air Force funds are invested in direct contracts. In order to promote the spread of technology beyond its direct contractors, the Air Force has established the Scientific and Technical Information (STINFO) program. The purposes of the program are to insure that "1) scientific and technical information makes the maximum impact on the advancement and development of Air Force technology, and 2) the scientific and technical information generated under Air Force R&D programs makes maximum contributions to the national economy."⁸ STINFO offices have been established at all major Air Force commands and laboratories. These offices are responsible for identifying elements of Air Force technology with potential for civilian applications and for ensuring that such information is made available to the potential users. The Air Force does not operate any information dissemination systems comparable to those of the Navy.

In addition to the STINFO program, the Air Force also has a potential contractor program, which certifies and registers non-government activities (organizations) for access to controlled scientific and technical information. Eleven Air Force laboratories and testing centers are also members of the Federal Laboratory Consortium.

The Department of Commerce. Since its establishment in 1913, the Department of Commerce has had a clear statutory mission to support technology diffusion. The Department's major functions related to this mission include:

1. assuring the fullest use of the nation's scientific and technical resources
2. administering the patent system
3. developing and publishing scientific, commercial, and engineering standards
4. operating the National Technical Information Service for federal research and development reporting
5. administering the Census Bureau for developing basic economic, business, scientific, and environmental information
6. encouraging economic growth by placing scientific findings in the hands of industry and entrepreneurs.⁹

Through the years, the Commerce Department has been involved in several major efforts to stimulate technology development and dissemination. In the Kennedy Administration, Assistant Secretary for Science and Technology J. Herbert Holloman launched the short lived Civilian Industrial Technology Program (CIT). The program was intended to 1) provide funds for university personnel to work on industrial research, 2) stimulate industry to undertake more risky or expensive R&D, 3) develop a university-industry extension service (similar to The Department of Agriculture model), and 4) collect and disseminate technical information. Industry and organized labor succeeded in killing the bulk of the program in Congress.

The "extension service," however, was established in 1965. The program, known as the State Technical Services Program, provided funds to non-profit institutions and public agencies. In turn, these organizations were expected to provide the following services:

- prepare and disseminate technical information
- establish state or interstate technical information centers
- provide referral services
- sponsor industrial workshops, seminars and training programs

The program resulted in the creation of a series of highly fragmented and generally underfunded programs in 30 states. By 1967, Commerce was funding 41 states and 16 "special merit" programs. The entire State Technical Services Program was eliminated in 1969.

In 1972, the Nixon Administration instituted the New Technology Opportunities Program. Despite initial discussions of additional tax incentives for private R&D, increased federal support of applied civilian research, changes in the anti-trust laws and new approaches to federal R&D management, the program presented to Congress prosed few drastic changes. The Nixon program called for modest increases in research funding and the creation of a \$40 million cooperative program under which the National Science Foundation and the National Bureau of Standards would jointly test incentives to stimulate R&D. The Office of Management and Budget impounded these funds.

The most recent and most extensive effort by the executive branch to promote technology diffusion came during the Carter administration.¹⁰ Assistant Commerce Secretary for Science and Technology Jordan Baruch conducted a domestic policy review on innovation in 1979. From this review emerged the President's Industrial Innovation Initiatives. These initiatives included three major programs--the Cooperative Generic Technology Program (COGENT); the Cooperative Automotive Research Program (CARP); and the Federal Industrial Energy Conservation Research, Development, and Demonstration Program.

COGENT was intended to promote generic (as opposed to applied) R&D by creating a number of Generic Technology Centers. These centers were to be

independent, non-profit entities. Industrial representatives who wished to participate in their research were to become members of the center and place a representative on the center's board of governors. Industrial participants would not be required to enter into any agreements restricting their use of information or patents developed at the center. These centers were also intended to provide a variety of consulting and technology evaluation services. Each center was expected to become financially self-sufficient after five years. The COGENT program was still in its formative stages when the Carter administration came to an end. The current administration has shown no interest in implementing COGENT or any other form of generic technology program.

The CARP program was intended to stimulate basic research on auto-related technologies. The federal government and the auto makers had agreed to focus their efforts on 12 general areas of auto technology. The program called for the auto makers to fund basic research projects in those areas at a location of their choice (i.e., in-house, university laboratories, government facilities, etc.). For each dollar spent, the federal government would have funded a matching amount of research. The type and location of this research were to be left to government discretion. Unlike the COGENT program, CARP called for little in the way of an institutional structure. Instead, it simply provided a mechanism for directing funds toward a particular type of research. Like COGENT, however, the program was eliminated by the Reagan administration before it was fully implemented.

Of the three programs advanced by the Carter administration, only the industrial energy conservation program was fully operational when eliminated by the Reagan administration. The elements of this program will be described later along with other Department of Energy activities.

At the present time, four organizations within the Department of Commerce remain at least minimally involved in the technology diffusion and transfer process. These four include the Patent Office, the National Bureau of Standards (NBS), the National Technical Information Service (NTIS), and the Minority Business Development Agency (MBDA--formerly the Office of Minority Business Enterprise). Of this group, NTIS and MBDA appear to be the most active. The patent system, while historically important in the transfer of technology, is relatively static. The participation of the Patent Office is largely limited to basic processing of patents and making information on patented items available. NBS, through its role as a developer of standards, has a great deal of contact with the scientific and technical community (in both industry and government). The majority of its activities are oriented towards the development and distribution of technical information.

NTIS had its earliest beginnings in 1951 in the Office of Technical Services (OTS). In 1967, OTS became the Clearinghouse for Federal and Scientific Information. The Clearinghouse was part of NBS, and served largely a library function. In 1972, NTIS was established and replaced the Clearinghouse as the cataloger and disseminator of federal research documents. In 1972, only DOD, NASA and the Atomic Energy Commission were providing information to NTIS. Today, NTIS is the largest disseminator of technical publications prepared by or for the federal government. The service receives documents and information from nearly all branches of the federal government. NTIS services are oriented toward general public consumption rather than highly specialized consumers of information. Still, NTIS serves as a single source for access to a wide range of government publications. Recent emphasis on fully covering all of its costs may lead to higher prices for NTIS services and somewhat reduced distribution.

Among the various components of the Department of Commerce, the Minority Business Development Agency may currently be the most active participant in the technology transfer field. In 1979, the Office of Minority Business Enterprise (now MBDA) established the Technology Commercialization Program.¹¹ The goal of the program was to establish a public/private partnership to identify and commercialize existing and newly developing technology. The program is targeted to meet the needs of the minority business community. MBDA currently operates ten Technology Commercialization Centers. These centers provide access to technical evaluations and act as brokers between technology developers and minority business clients. Each center has a resource committee made up of representatives from industry and government. Committee members currently represent 40 Fortune 500 companies and 18 federal agencies. Three of the ten centers are primarily technically oriented. These centers provide technical evaluations to clients. The remaining seven centers act as brokers in specialized fields, matching technologies, financing, markets, adaptive engineering and qualified minority firms or entrepreneurs.

In addition to the ten centers, the Technology Commercialization Program also maintains several data bases. These include:

- The Techtra Database - MBDA is one of the major funders of this data base.
- Tech Lab - a data base which allows MBDA to survey federal laboratories for potentially transferable technologies.
- Tech Uni - a data base similar to Tech Lab used in surveys of university laboratories.
- A data base identifying over 15,000 minority business firms by SIC code and capability.

At present, MBDA has approximately 60 active projects in the Technology Commercialization Program (with a similar number on hold for one reason or another). Despite general cutbacks in the Commerce Department, this program has actually received a small increase in funding for 1983. MBDA is currently working on expanding its network of contacts (both within and outside of the minority community) and developing a closer relationship with the venture capital community.

Aside from the efforts described above, the Commerce Department is not particularly active in the technology transfer field at this time. The Stevenson-Wydler Technology Innovation Act of 1980 required Commerce to:

- Create an Office of Industrial Technology
- Establish Centers for Industrial Technology (affiliated with universities and other non-profit organizations)
- Create a National Industrial Technology Board
- Establish a Center for the Utilization of Federal Technology (CUFT)¹²

Under the Reagan administration, Commerce has declined to take many of these steps (although a CUFT has been established within NTIS). The Department will concentrate instead on the areas of productivity and foreign competition. The Department will apparently place less emphasis on picking technological "winners" for American industry and more emphasis on basic information activities.

On the whole, the Department of Commerce's record in the technology transfer field is less than spectacular. Commerce may hold the dubious distinction of having launched and aborted the largest number of technology programs of any federal department or agency. To some extent, the Department's difficulties in developing and maintaining an effective program promoting innovation and technology diffusion can be attributed to the fact that:

1. Commerce lacks a particularly strong, well focused constituency or client group.
2. Commerce is not itself an innovator or generator of technology (and thus must act more as a catalyst or broker).

Despite the shortcomings, the Department of Commerce does provide a number of services which support technology development and transfer (e.g., patents, NBS standards, NTIS information services, etc.). For the most part, Commerce has been and continues to be strongest in the area of information dissemination--due largely to the efforts of NTIS. The MBDA Technology Commercialization Program, however, does seem to have achieved a fair degree of success. MBDA's network of contacts and relationship with its client group seem to allow the agency to function fairly effectively as a technology broker.

The Department of Agriculture (USDA). In contrast with the experiences of most federal agencies, the USDA has been quite successful in transferring new technologies to the U.S. farm community. USDA has maintained a continuous program with a modest but stable level of funding over a great many years. USDA technology transfer activities are highly decentralized, socially institutionalized (i.e., economically and politically incorporated into society), and well integrated with the Department's basic functions. Much of USDA's success can be attributed to the nature of its client group and its relationship to that group. In general, members of the agricultural community tend to be engaged in atomistic rather than rivalrous competition, are actively involved in setting research priorities for the Department, are generally educated and prone to experiment with new technology by nature, and are part of a large, well defined group.¹³

The basic components of the USDA technology diffusion activities are the Agricultural Research Service, the Cooperative State Research Service, and the Extension Service. The Agricultural Research Service operates laboratories

and state experiment stations at over 148 locations. The Cooperative State Research Service is involved in research program planning and coordination and encouraging cooperation among the states and between the states and their federal research partners. The Extension Service represents the largest off-campus informal education system in the world. Supported by federal, state, and county governments, the Extension Service operates an office in virtually every county in the United States. In addition, the National Agricultural Research and Extension Users Advisory Board (a group of 21 citizens representing producers and consumers) reviews and advises on USDA policies, research priorities, and resource allocations.

USDA technology developed in the federal laboratories, state experiment stations and land grant universities is transferred to the agricultural sector in a number of ways. By far the most important channel is through the Extension Service's highly decentralized system of county agents. These individuals are accessible, familiar, trusted sources of information for potential technology users in the farm community. Land grant universities and experiment stations also engage directly in a number of dissemination and outreach activities. In addition, USDA uses a wide variety of mechanisms, ranging from technical publications and educational programs to brief radio presentations and exhibits at state fairs.

In addition to the factors already mentioned, successful transfer of USDA technology is also facilitated by the following characteristics:

- a limited number of approvals are required in order to adopt USDA technology
- the decentralized Extension Service system facilitates a great deal of personal contact between potential users and generators of technology

- the Department's client group is the targeted audience, as opposed to some other segment of the general economy with which it does not have an established relationship.

Each of these factors has played a significant role in the success of USDA's technology transfer efforts. Because these factors are not likely to be duplicated in other agency experiences, the opportunities for directly applying the USDA model in other areas appear to be limited. Few federal agencies are in a position to duplicate USDA's decentralized structure or close relationship with its client group.

Within the Department of Agriculture, the U.S. Forest Service (USFS) has also been active in the technology transfer field. The Forest Service, like USDA, is a largely decentralized organization. Applied research and activities have been a major part of the USFS program for more than 80 years. In 1972, the Forest Service contracted with the Center for Research on Utilization of Scientific Knowledge (CRUSK) at the University of Michigan to critically review its efforts in this area. Shortly afterwards, a national workshop on Research Implementation was conducted for Forest Service personnel. Out of this workshop came a number of recommendations for increasing the Forest Service's ability to transfer technology. Since the early 1970's, the Forest Service has taken a number of steps to implement these recommendations.

Perhaps more so than any other federal agency, the Forest Service has emphasized the need to integrate technology transfer functions and responsibilities within the agency's basic structure and mission. Technology transfer responsibilities have been incorporated in the position descriptions of line and staff personnel. In addition, the Forest Service has attempted

to adjust its reward system to reward research personnel for achievements in the area of implementation. Technology transfer responsibilities are distributed throughout the Forest Service, and are allocated in the following manner:

Deputy Chiefs - responsible for leadership and support of transfer efforts; foster development of technology transfer plans.

Technology Transfer Council - includes one Deputy Chief from each area; responsible for establishing agency-wide policies and recommending decisions on technology transfer activities.

Technology Transfer Staff - Washington, D.C. - serves as focal point for all USFS transfer activities; oversees all USFS transfer activities in Washington and in the field offices.

Technology Transfer Coordination Committees - established by Regional Foresters, State Directors and Area Directors; composed of Research Coordinators and Experiment Station Assistant Directors for Planning and Application; set priorities for research application needs, make recommendations on assignments of personnel to develop new technology transfer plans.

Assistant Directors for Planning and Application - have primary responsibility for promoting research applications and implementation at the field level; one Assistant Director for Planning and Application in each Experiment Station.

Experiment Station Information Offices - provide technical communication expertise to teams or work units preparing technology transfer plans; prepare and distribute information packages to potential users.¹⁴

In addition, the Forest Service has worked with the Extension Service to establish joint locations for extension foresters and Forest Service specialists at research centers and land grant universities.

Although it has taken a number of steps to institutionalize its technology transfer program (and produced many detailed transfer plans), the Forest Service program is not without its problems. An internal evaluation of the agency's transfer efforts from 1978 through 1981 identifies the following

factors as remaining obstacles to successful institutionalization:

1. Research and National Forest Systems (NFS) reluctance to accept State & Private Forestry (S&PF) leadership in technology transfer.
2. Technology transfer activities supported by research which cannot be completed when qualified specialist counterparts in NFS and S&PF are not available to work with research scientists.
3. Technology transfer planning that is obstructed where research scientists are reluctant to involve NFS or S&PF specialists whom the scientists consider to be unqualified.
4. Technology in which specialists are interested but is not available for transfer when scientists are reluctant to release research findings until additional studies are completed.
5. Technology transfer that is inhibited by poorly defined research and S&PF responsibilities for technology development.
6. Experiment Station Assistant Directors for Planning and Application who spend a disproportionate amount of time on activities relating to the planning element.
7. Technical expertise in technology transfer is not readily available to USFS field units.
8. USFS executive and administrative personnel who are not supportive of technology transfer.
9. Some Washington Office functional staffs still believe that the purpose of the Washington Office Technology Transfer Staff Group is to do the technology transfer rather than to provide leadership, coordination and support.¹⁵

The same evaluation went on to note that much of the technology available for transfer within the Forest Service is of the supply push (as opposed to demand pull) type. This reflects the lack of an effective process for identifying research needs. Since available evidence indicates that the potential for success is much greater in a demand pull situation, the Forest Service must find better ways of involving clients in determining research needs. User participation helps insure research relevance to user needs. The evaluation report also indicates the need for at least one position in the Washington Office staffed by a knowledgeable professional from the technology transfer field.

Overall, the Forest Service has achieved a greater degree of success in institutionalizing technology transfer activities than most other federal agencies. Their efforts in this area and in the development of transfer plans have served as models for other agencies. Still, these activities are not immune to budget and personnel cuts. In the last two years, Forest Service transfer activities have declined substantially.¹⁶ Restrictions on publications have further reduced the program's effectiveness. The Forest Service traditionally has relied on documents and publications as one of its primary transfer mechanisms. Thus, while many pieces of the transfer program are still in place, they are currently receiving less attention.

The Small Business Administration (SBA). SBA's role in the technology transfer process has largely been that of a facilitator or middleman. Because it is not itself a generator of technology, SBA has tended to rely on other federal agencies. Through the mid-1960s, SBA concentrated primarily on assisting small businesses in procuring government R&D contracts. SBA participated in joint efforts to promote small business contracting with NASA, DOD and the AEC. In 1966, SBA created a Technology Utilization Division, designated to assist small businesses in applying federal technology.

The Technology Utilization Division operated field offices in eight major cities. The activities of these offices varied greatly, but generally included specifying technical problems to be solved; identifying information sources; providing limited information searches (often in conjunction with other agencies or institutions); locating consultants; and obtaining assistance from retired business executives affiliated with SBA's SCORE program. In addition to these specialized centers, SBA also maintains more than 80

general purpose field offices throughout the country. These offices engage in a variety of technical assistance and information disseminating activities. Through its field offices, SBA has attempted to promote small business adoption of federal technology through conferences, publications (usually free of charge or at reduced cost), and consulting and technical assistance services.

SBA's technology transfer efforts appear to have had a limited impact. On the positive side, SBA's dispersed system of field offices and the fact that it deals with a relatively alert audience (i.e., small businesses actively seeking ways to improve their performance) have allowed the agency to reach a large number of potential users. To its credit, SBA has also done a particularly good job of mixing management and technical information for use by its clients. It is not clear, however, that these efforts have resulted in substantial amounts of actual transfer. Often SBA's field offices have been too sparsely staffed to respond effectively to the assistance requests of clients. Likewise, SBA representatives at NASA and DOD procurement offices were rarely able to overcome the reluctance of contracting officers to disclose technical data. Furthermore, much of the technology-related information distributed by the agency has reached small businesses who lack the financial, technical and managerial resources required for adoption. SBA loan and assistance programs have only partially addressed these constraints.

To summarize, SBA transfer efforts have been facilitated by the following factors:

- the agency's decentralized field office structure
- SBA's role as a trusted source of information
- the relatively close relationship that exists between the small business community and the agency.

The following factors, however, have generally inhibited successful transfer:

- SBA is not itself a generator of technology, and thus is dependent on the cooperation of other federal agencies
- SBA programs often have been inadequately staffed and funded
- many of SBA's small business clients lack the skills and/or resources necessary for successful adoption of new technology.

Under the Reagan administration, SBA technology transfer activities have been severely curtailed. Funding for the SBA Technical Assistance program has been completely eliminated for 1983.¹⁷ As a result, it is unlikely that SBA will be able to continue to play an active role as a link between technology generators and potential users in small business. The scope of the agency's efforts in the future may be confined to limited distribution of publications and provision of technical assistance through its remaining programs.

The Department of Energy (DOE). The Department of Energy and its predecessor agencies (particularly the AEC and the Energy Research and Development Administration--ERDA) also have engaged in a variety of technology transfer activities. Of this group, the AEC was probably the most active. From its inception, the AEC had a strong commitment to the development and diffusion of nuclear technology. This attitude contrasts sharply with that of more mission-oriented agencies such as DOD. AEC established a vigorous program for disseminating unclassified R&D information, and placed professional referees in each of its laboratories to evaluate reports prepared by contractors and AEC staff for declassification and distribution. In the early 1970s, the AEC operated 20 specialized data and information centers. The AEC's Division of Industrial Information also supported a variety of libraries and information depositories in the U.S. and throughout the world.

In addition to distribution of publications and information, the AEC relied upon a variety of other mechanisms to encourage technology diffusion. As early as 1954, the AEC established an Industrial Cooperation Program which allowed potential users of nuclear technology to meet and work alongside its developers. In the late 1960s, the AEC established Industrial Cooperation Offices at both Argonne and Oak Ridge National Laboratories. These offices were responsible for responding to inquiries from industry and disseminating information on laboratory innovations. These offices were also directed to become familiar with the technical needs of particular segments of the nuclear industry. In addition, the Commission made a conscious effort to change contractors periodically as a way of increasing the dissemination of knowledge and technology. The AEC also made use of access permits, which allowed industrial organizations to obtain restricted data relevant to civilian applications of nuclear technology.

During its lifetime, the AEC served as the primary developer of nuclear technology. Due to the nature of the technology and its security implications, the AEC was required to play a major role in regulating the integration of nuclear technology into the general economy.¹⁸ The AEC achieved a relatively high degree of success in transferring nuclear technology to specialized segments of the economy. These successful transfer experiences, however, rarely involved horizontal transfers of technology (i.e., use of the technology in an unrelated field). By far, the largest beneficiary of AEC transfer efforts appears to have been the commercial nuclear power industry.

In its relatively brief history, DOE has promoted technology transfer largely through the following three programs:

- DOE laboratory participation in the FLC
- the Bartlesville Energy Technology Center's Enhanced Oil Recovery Technology Transfer program
- the Federal Industrial Energy Conservation Research, Development and Demonstration program (no longer in operation).

Each is described briefly below.

FLC Participation:

DOE operates 41 research and development laboratories of widely varying size. Ten of these laboratories, mainly the large multiprogram laboratories, are members of the FLC. Several of these laboratories (including Los Alamos, Sandia, and Livermore) participate quite actively in FLC programs. In response to the Stevenson-Wydler Technology Innovation Act, DOE has established an Office of Research and Technology Applications at each of these major laboratories. These offices are responsible for identifying transfer opportunities, developing and implementing transfer plans, and preparing annual reports.

Enhanced Oil Recovery Technology Transfer:

Since 1978, DOE's Bartlesville Energy Technology Center (BETC) has been operating a transfer program designed to promote enhanced oil recovery (EOR). This program relies on a variety of mechanisms to assemble and distribute information to potential users of EOR technology (oil producers, service and supply organizations, engineering firms, consultants, etc.).¹⁹ A critical element of the program is a series of extensive EOR data bases compiled by BETC. DOE uses publications, films, workshops, symposia, direct access to its data bases, and interaction between industry representatives and EOR project managers to achieve transfer. Recent uncertainty about the future of BETC (the center is scheduled to be turned over to a private contractor) has affected, but not eliminated, the EOR transfer program.

Energy Conservation Research and Development:

The Federal Industrial Energy Conservation Research, Development and Demonstration Program was instituted during the Carter administration. The goal of the program was to accelerate the adoption of energy saving technology by industry. The program called for DOE to partially fund projects with potentially high rates of return that were too risky to be undertaken alone by private sponsors. The selection criteria developed ultimately required DOE to pick technological "winners." Despite this apparent limitation, the program was embraced and used by industry. Observers credited its success to the following:

- the program concentrated on process innovation (as a result, the uncertainties were limited to technological and engineering concerns--as opposed to economic/market concerns);
- competent management by DOE;
- a generally low profile for the program as a whole.²⁰

The energy conservation research program was not funded by the Reagan administration.

In addition to the three programs described above, DOE also operates a Technical Information Center that distributes research reports and other documents. DOE also provides material to NTIS for dissemination.

In general, DOE has enjoyed limited success in the technology transfer field. The BETC EOR transfer program appears to have significant potential (if support is continued), due to the close relationship that exists between BETC and the oil and gas industry. The long term impacts of the other programs are less clear. To date, DOE laboratory participation in the FLC activities still consists largely of problem solving on a consulting basis. DOE as a whole appears to have suffered from a continually changing sense of purpose and a limited (and often adversarial) relationship with the energy industry. AEC activities are important only in an historical sense.

Other Departments and Agencies:

In addition to the federal departments and agencies discussed above, a handful of others have also pursued technology transfer activities of one form or another. This group includes segments of the Department of the Interior, the Department of Transportation, the Department of Housing and Urban Development, and the Environmental Protection Agency. The efforts of each of these organizations are described briefly below.

Within the Interior Department, two groups--the Office of Water Research and Technology (OWRT) and the Bureau of Mines--at one time had active technology transfer programs. A 1971 amendment to its authorizing legislation specifically called on OWRT to undertake transfer activities. In response, OWRT established a program to promote technology transfer through the network of water resource research centers it supported at universities throughout the country. In 1974, an Assistant Director of OWRT was appointed to coordinate those activities. The OWRT program encouraged researchers to focus more of their efforts on application. Under the Reagan administration, OWRT has been reconstituted as an office of the Bureau of Reclamation with lessened funding, fewer functions and reduced emphasis on transfer activities. The Bureau of Mines at one time had a Mining Research Technology Transfer Group within the Mine Systems Engineering Division. This group used the Bureau's close relationship with the mining industry as a vehicle for transferring improvements in mining technology. At the present time, the Bureau of Mines no longer has a specifically designated technology transfer group.

The Department of Transportation's (DOT) technology transfer efforts have been oriented towards state and local government. DOT has an Office of Technology Sharing in the Secretary's Office. This office is responsible for insuring that the needs of state and local government are given full consideration in the establishment of DOT research projects and technical

assistance programs. DOT's Transportation Systems Center (a major research facility in Cambridge, MA), also has an Office of Technology Sharing. In addition, each Federal Highway Administration State Division Office has one individual who serves as a technology transfer coordinator. Four DOT laboratories are also members of the FLC. Overall, DOT transfer activities are fairly passive. The major emphasis is on directing research priorities. Only a very limited effort is made to promote transfer once research has been completed.

At one time, the Department of Housing and Urban Development (HUD) was actively involved in the technology transfer field. Many of the department's efforts were coordinated by the now defunct Division of Product Dissemination and Transfer. Probably the most famous of all the HUD programs in this area was Operation Breakthrough. Put simply, Operation Breakthrough was HUD's attempt to improve the technology of the U.S. home building industry through applied research and development. In a sense, HUD attempted to duplicate some of the successes of the USDA model. On the surface, homebuilders appeared to have much in common with farmers. Both industries were highly fragmented and filled with individual producers engaged in atomistic competition. Operation Breakthrough demonstrated, however, that the agricultural model cannot be easily duplicated. The HUD program ultimately had little impact on the housing industry and is generally regarded as a major failure. Retrospective analysis indicates that Operation Breakthrough suffered from the following weaknesses:

- While builders may not engage in rivalrous competition, producers and suppliers of building materials and equipment do. Applied government research in this area posed a direct threat to these groups.

- Unlike agriculture, housing lacked a broad scientific base or scientific community from which an applied research and development effort could be launched.
- HUD was neither a major builder nor purchaser of non-subsidized housing. Thus, the department lacked the ability to select designs which would ultimately succeed in the marketplace.²¹

Since 1977, HUD has also operated a program designed to improve the financial management capabilities of state and local governments. Known as the Financial Management Capacity Sharing program, this effort has relied on publications, conferences, workshops and direct technical assistance to disseminate management information to state and local officials. In February 1981, the program's focus was shifted somewhat in response to requests from local government. The program, now known as the Governmental Capacity Sharing Program, focuses primarily on the areas of 1) management, planning, and financing of capital infrastructure projects and 2) creation of public/private partnerships.²² HUD officials believe the capacity sharing program has contributed to substantial improvements in financial management at the state and local levels.

Shortly after its establishment, the Environmental Protection Agency (EPA) entered into a joint program with NASA designed to transfer NASA technology to the field of environmental science. The program relied on fairly traditional mechanisms and by all accounts appears to have had little impact. In 1973 the program was terminated. At the present time, EPA's Industrial Environmental Research Laboratory in Cincinnati, Ohio produces a monthly technology transfer newsletter. This publication contains general descriptions of recent EPA research projects and findings. Other than the newsletter, EPA does not appear to be actively engaged in transfer activities at this time.

Conclusion

The brief description of federal technology transfer activities provided above is admittedly incomplete. The experiences of each agency could be described in much greater detail, and there are a number of organizations (such as the Department of Health and Human Services and its predecessors, the National Science Foundation and the Library of Congress) whose activities have not been discussed at all. Even this limited review of federal transfer experiences, however, is sufficient to demonstrate the wide range of approaches that have been used. While many agency programs may have fallen short of their objectives, all of these experiences provide valuable lessons for managers of current and future federal technology transfer programs.

KEY TO FOOTNOTES

1. Granville W. Hough, Technology Diffusion: Federal Programs and Procedures (Mt. Airy, Maryland Lomond Books 1975), pp. 77-103; U.S. House of Representatives, Committee on Science and Technology, Subcommittee on Science, Research and Technology, Hearings on Implementation of P.L. 96-480, The Stevenson-Wydler Technology Innovation Act of 1980 (Washington, D.C., U.S. Government Printing Office, 1982), pp. 56-60.
2. Herbert I. Fusfeld, Richard N. Langlois and Richard R. Nelson, The Changing Tide: Federal Support of Civilian-Sector R&D (New York, New York University Graduate School of Business Administration, Center for Science and Technology Policy, 1981), pp. 102-103.
3. George F. Linsteadt, Federal Laboratory Consortium for Technology Transfer, Technical Information, Final Report (Washington, D.C., National Science Foundation, 1980). See pages 22-33 for a complete list of FLC members.
4. U.S. House of Representatives, Committee on Science and Technology, Subcommittee on Science, Research and Technology, Hearings on Implementation of P.L. 96-480, The Stevenson-Wydler Technology Innovation Act of 1980 (Washington, D.C., U.S. Government Printing Office, 1982). See pp. V - XXXVII.
5. Granville W. Hough, Technology Diffusion: Federal Programs and Procedures (Mt. Airy, Maryland Lomond Books, 1975), pp. 160-161.
6. Granville W. Hough, Technology Diffusion: Federal Programs and Procedures (Mt. Airy, Maryland Lomond Books, 1975), p. 162.
7. U.S. House of Representatives, Committee on Science and Technology, Subcommittee on Science, Research and Technology, Hearings on Implementation of P.L. 96-480, The Stevenson-Wydler Technology Innovation Act of 1980 (Washington, D.C., U.S. Government Printing Office, 1982). See pp. 489-508 for a complete description of the current Navy program.
8. U.S. House of Representatives, Committee on Science and Technology, Subcommittee on Science, Research and Technology, Hearings on Implementation of P.L. 96-480, The Stevenson-Wydler Technology, Innovation Act of 1980 (Washington, D.C., U.S. Government Printing Office, 1982), p. 511.
9. Granville W. Hough, Technology Diffusion: Federal Programs and Procedures (Mt. Airy, Maryland Lomond Books, 1975), p. 165.
10. Herbert I. Fusfeld, Richard N. Langlois and Richard R. Nelson, The Changing Tide: Federal Support of Civilian-Sector R&D (New York, New York University Graduate School of Business Administration, Center for Science and Technology Policy, 1981). See p. 15 and pp. 82-97.
11. Conversation with David Lettes, Director of the Technology Commercialization Program, Minority Business Development Agency, U.S. Department of Commerce, November 26, 1982.

12. U.S. House of Representatives, Committee on Science and Technology, Subcommittee on Science, Research and Technology, Hearings on Implementation of P.L. 96-480, The Stevenson-Wydler Technology Innovation Act of 1980 (Washington, D.C. U.S. Government Printing Office, 1982). See introduction and overview as well as pp. 20-84.
13. Granville W. Hough, Technology Diffusion: Federal Programs and Procedures (Mt. Airy, Maryland Lomond Books, 1975), pp. 77-103; U.S. House of Representatives, Committee on Science and Technology, Subcommittee on Science, Research and Technology, Hearings on Implementation of P.L. 96-480, The Stevenson-Wydler Technology Innovation Act of 1980 (Washington, D.C., U.S. Government Printing Office, 1982), pp. 56-60.
14. U.S. Forest Service, Department of Agriculture, Forest Service Manual Interim Directive No. 7 Washington, D.C., March 30, 1982.
15. See U.S. Forest Service, Department of Agriculture, Milestone-Technology Transfer in the Forest Service: Report on Technology Transfer Staff Accomplishments and Evaluation, 1978-1981 Washington, D.C. July 1981.
16. Interview with Harold G. Marx, U.S. Forest Service, Washington, D.C. August 13, 1982.
17. Telephone conversation with Thomas Cheyney, Small Business Administration, Washington, D.C., December 5, 1982.
18. Samuel I. Doctors The Role of Federal Agencies in Technology Transfer (Cambridge, MA, The MIT Press, 1969), pp. 53-55 and 173-176.
19. See Department of Energy Enhanced Oil Recovery Technology Transfer Planning Document Bartlesville Energy Technology Center, Bartlesville, Oklahoma, February 1979.
20. Herbert I. Fusfeld, Richard N. Langlois and Richard R. Nelson, The Changing Tide: Federal Support of Civilian-Sector R&D (New York, New York University Graduate School of Business Administration, Center for Science and Technology Policy, 1981), pp. 94-96.
21. U.S. House of Representatives, Committee on Science and Technology, Subcommittee on Science, Research and Technology, Hearings on Implementation of P.L. 96-480, The Stevenson-Wydler Technology Innovation Act of 1980 Washington, D.C., U.S. Government Printing Office, 1982), pp. 58-62.
22. Telephone conversation with Hartley Phipps, Office of Policy Development and Research, Department of Housing and Urban Development, January 31, 1983.

APPENDIX G-

NASA Field Center Perspectives

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NASA FIELD CENTER PERSPECTIVES

During February and March 1983, the Study Director visited the seven in-house NASA Field Centers: Marshall Space Flight Center, Goddard Space Flight Center, Langley Research Center, Kennedy Space Center, Johnson Space Center, Lewis Research Center, and the Ames Research Center. The purpose was to discuss with senior staff at each Center their perceptions of NASA technology transfer efforts, their receptivity to the new emphasis upon a broadened program of technology transfer, and to solicit their views on how such efforts might be improved over those in the past. In addition, these discussions included recent experience at the various Centers in cooperative efforts with industry, particularly nonaerospace industry, and perceptions about each Center's role in advancing technology. In the course of these visits, the Study Director interviewed each of the Center Directors and a total of 45 other senior staff.

The Feasibility of A New Emphasis Upon NASA Technology Transfer

Discussions with the Center Directors and senior staff at the Field Centers revealed a general consensus on three points regarding the feasibility of a new emphasis by the NASA Administrator upon technology transfer--especially that directed toward nonaerospace industry: (1) a willingness to embrace such a program of emphasis by the Administrator, coupled with some skepticism related to the past history of the Technology Utilization Program; (2) a general acceptance and enthusiasm for a broader concept of technology transfer, one beyond the formal Technology Utilization Program; and (3) agreement that the key to substantially improved technology transfer is to catch the interest of industry (especially nonaerospace industry) and forge more effective links with industry.

Field Center officials generally appear to be willing, and often eager, to join in a renewed emphasis by the NASA Administrator on a program of technology transfer focused toward nonaerospace industry. Fundamental caution expressed relates to past experience with the Technology Utilization Program which has suffered from time to time: (1) a lack of continuity of leadership or interest from top levels of NASA leadership, (2) variations in resource allocation, (3) inadequate cues from past Administrators regarding its priority, (4) uneven follow-up in program execution, and (5) insufficient means to institutionalize the process so that there is continuity of effort beyond changes in Headquarters leadership.

Officials interviewed at the Field Centers believe that the current Administrator is fully capable of overcoming this past legacy, building on the strengths of the past program while instituting new efforts and promising directions. Clear direction and commitment by the Administrator and his continuing attention to a renewed technology transfer effort would be welcomed. Concurrently, Field Center leadership will look for assignment of priorities and allocation of resources commensurate with the program objectives. It is widely recognized that one of the most difficult challenges is that of "institutionalizing" the technology transfer process into the day-to-day activities of NASA. Interestingly, persons at several of the Field Centers suggested including technology transfer activity within an individual's performance assessment--not unlike that for monitoring and judging the equal employment function. Managers and supervisors (Field Centers and Headquarters) would then have this element considered in the overall assessment of their performance.

There was general enthusiasm for the broader concept of technology transfer beyond that of the formal Technology Utilization Program. The broader context would include all systematic efforts to transfer technology by formal or

informal means, including ad hoc problem solving, the use of NASA facilities to explore a technology problem, and the exchange of data, information, techniques, etc. through site visits, telecommunications, or publication--principally focused on nonaerospace industry, but not limited to that context.

The concept behind this broader approach to technology transfer is the model of the relationship between NACA and the aircraft and related industry--expanded to the extent that it is practical. It was recognized that this approach to technology transfer will be more easily carried out in the research centers (Ames, Langley, and Lewis) where half or more of the activity is conducted through in-house laboratories. Major project centers such as Goddard, Johnson, and Marshall are unlikely to have as many opportunities for this type of transfer, since a substantially larger proportion of their work is conducted through contractors. However, each has special in-house capabilities, and a relationship with principal contractors that have the potential for expanding effective transfer. The most challenging environment for technology transfer is probably that at the Kennedy Space Center. The mission of preparation and launch of space vehicles involves intense operational pressures that inhibit attention to transfer activities. But even here examples of successful past transfers were cited, and there was an optimism about their capability to expand this in the future because of their close operating linkages to industry.

There is universal acknowledgement among Center Directors that substantially improved technology transfer involves capturing the interest of industry and developing more effective linkages for cooperation in the exchange of information. One of the most important steps that can be taken is to provide more opportunities for personal, face-to-face contact between Field Center scientists and engineers and those in nonaerospace industry. Sadly, these opportunities have been substantially reduced in recent years because

of travel restrictions limiting attendance at professional meetings, symposia, sessions of technical societies, etc. Consistently one finds that ad hoc problem solving activities which result in substantially successful transfers of technology often have their origins in the meeting of an industrial engineer and a NASA engineer at a professional conference. A second channel that was described as relatively underdeveloped is that of using the publications of technical and professional societies most often read in nonaerospace industry. Such publications can provide a means for more widely publicizing important technological advances stemming from NASA research and development. It was acknowledged that these channels need to be pursued at both the Headquarters and the Field Center levels.

Finally, NASA has unusually broad flexibility, stemming from the 1958 Space Act, to enter cooperative ventures or personnel exchanges in pursuit of NASA's program purposes. This avenue for technical exchange also remains relatively underdeveloped compared to its potential. Several of the Field Centers have initiated preliminary efforts to explore these possibilities as means for broader cooperation with nonaerospace industry. For example, at the Lewis Research Center consideration is being given to instituting, on a trial basis, an industrial fellowship that would permit an industrial scientist to work in a Lewis laboratory for up to a year, pursuing areas of mutual interest. For several years the Ames Research Center has derived benefits of a cooperative venture in the research of space law through mutual efforts with the University of California Hastings College of the Law, the Davis School of Law and the University of Santa Clara in what is titled the "NASA-Ames/University Consortium for Astro Law Research." In these endeavors each "partner" brings its special resources for the cooperative benefit of those participating.

Lessons From Recent Experience

Although there was some variation from one Field Center to another, there was a general consensus regarding technology transfer and cooperative efforts with industry on five points. These were: (1) avoid overstructuring such efforts, (2) focus such efforts on technical areas of either NASA's strength or special NASA interest, (3) recognize technology transfer as a two-way street, (4) seek opportunities for participation with industry in "neutral third party" settings such as university consortia and professional meetings, and (5) expand efforts to document and to better understand the economic and other benefits flowing from technology transfer.

Based on past experience, it appears that the largest number of transfers, and often those that appear to occur most "naturally," are of an ad hoc nature where there rarely is any formal agreement or paper exchanged between the parties involved. The typical modus operandi between NACA and aircraft companies rarely involved any formal agreement. Prototypes were built by the manufacturer, tests were run in NACA facilities, data were exchanged and eventually analyzed--nearly always on no more than verbal agreement. This may not always be possible with more complex, expensive undertakings. However, the strong feeling within the Field Center is that NASA Headquarters needs to provide a principal focal point for the technology transfer function and broad guidance to the program, but that the actual operations should be handled in a decentralized fashion within the respective Field Centers. The more formal the process becomes, the less likely are the informal networks and relationships to develop and grow to fruitful and successful transfers.

Second, since the effort devoted to technology transfer necessarily must be limited, those efforts should be focused in the technical areas where NASA

has special strengths (in research, problem solving, or particular facilities), or in areas of special interest in which NASA wants to learn more or to expand its capabilities and can learn from universities or industry. It was this characteristic of "leading from its strength" that created NACA's excellent reputation. As one Center Director put it, "We possess two things that industry sought: (1) special research and problem solving capabilities and (2) unique facilities with highly trained support staff not available elsewhere."

The technology transfer process needs to be recognized as a two-way street (by both NASA and industry). It is generally acknowledged that transfer occurs most successfully when all parties to it benefit and share mutual interests. It is readily acknowledged in the Field Centers that the image of the Technology Utilization Program has not always reflected these characteristics, but occasionally reflects a "hard sell" image. A fresh emphasis on cooperation, with information and benefits flowing in both directions, appears more acceptable throughout the Field Centers. And it is one that fits more naturally the general process of technology diffusion.

Experience at NASA research centers suggests that initial linkages with nonaerospace industry representatives have been relatively successful when participants are involved in common technological undertakings, such as those found in university consortia. They offer "neutral" ground for the pursuit of technical objectives in an environment that is conducive to information exchange--both giving and receiving. Field Center personnel confirm the utility of this type of interaction and believe that its expansion could be accomplished with little difficulty and substantial benefit.

Finally, there was general recognition among Field Center officials that even a most successful program of technology transfer will not be able to be sustained over time without concurrent efforts that will document its success, and lead to an improved understanding of both the process and the benefits accrued from it.

Areas of Technical Strength

In the process of exploring various aspects of technology transfer with Center officials, they were asked to list several areas in which their particular Field Center excelled or was at the "leading edge" of technology. In aggregate, these areas are:

1. aeronautics
2. aerospace propulsion
3. bioinstrumentation
4. ceramics
5. composite materials
6. computer applications
7. computer applications to large engineering models
8. electronic instrumentation and flight control
9. full scale manufacturing pilot testing
10. human factors
11. large scale systems analysis
12. launch preparation and control
13. materials (including wear, fatigue)
14. measurement techniques
15. safety, fire control and flame retardant materials
16. satellite tracking and data reduction
17. simulators
18. Stirling engine technology
19. systems management
20. toxic materials handling
21. tribology

APPENDIX H

Evaluating Recommendations for Enhancing
NASA's Technology Transfer Policy

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EVALUATING RECOMMENDATIONS FOR ENHANCING
NASA'S TECHNOLOGY TRANSFER POLICY

DRI has offered two recommendations for reconstituting NASA policy to reflect an expanded concept of technology transfer. The first of these recommendations addresses the need for an internal policy change at NASA. Whereas technology transfer has some vocal support and a budget of around \$9 million, it ranks as a mission of minor secondary importance within the space agency. Expanding our knowledge of space is, and should be, NASA's primary mission, but the effect of relegating technology transfer to a marginal secondary role has been to enervate the program. While recognizing that technology transfer is not NASA's primary mission, DRI recommends that NASA establish technology transfer as a vital activity of the agency.

The second recommendation is that NASA expand the channels of cooperation with industry. These channels provide avenues for learning what industry needs and how it operates--critical components to successful technology transfer.

Specific courses for implementing both recommendations are offered. In order to establish technology transfer as a vital activity of NASA, it is recommended that NASA:

1. Focus the coordination of technology transfer activities in NASA by creation of a new position at the Associate Administrator or Associate Deputy Administrator level.
2. Delegate technology transfer activities to Field Centers.
3. Increase the allocation of resources (funding and manpower) to technology transfer activities.
4. Establish a technology transfer activity fund at each Field Center under the authority of the Center Director.
5. Establish a NASA-wide recognition program for extraordinary accomplishment in technology transfer activities.

In order to expand the channels of cooperation with industry, it is recommended that NASA:

1. Base cooperative efforts on areas of NASA technological strength or areas of special interest to NASA.
2. Join with industry in industry/university consortia for research and technology exchange.
3. Expand joint endeavor agreements beyond the current Materials Processing in Space Program.
4. Bring industry representatives into NASA's technology planning process.
5. Test the feasibility of encouraging engineers, representing industry, to search and assess NASA technology for applications.
6. Explore means to use industry-related publications as channels to publicize NASA technology.
7. Review with the U.S. Air Force additional means to expand or assure the aerospace industrial base.

Implementing these recommendations would involve a number of organizational changes, resource decisions, and technical details which are beyond the scope of this policy paper. To the extent possible, however, DRI has screened the recommendations for their practical feasibility.

The Screening Criteria

Four broad criteria were considered as factors for screening the recommendations. These criteria are:

- NASA feasibility,
- Industry feasibility,
- Public policy issues, and
- Future-oriented issues.

Evaluating an option in terms of its feasibility for NASA involves asking whether the proposed action has a reasonable chance of being authorized and successfully carried out within NASA. For a recommendation to succeed, it must have some compatibility with the agency's mission, its

resource capability, its organizational structure, and its way of doing business. It is not necessarily the case that the best options are those which conform most readily to the existing structure, however. A program which requires a significant reallocation of resources may disturb some existing hierarchies, but this type of turbulence may be what is needed to achieve significant policy change. For any recommendation, its potential benefits need to be weighed against the problems, resistance, costs, and organizational changes inherent in implementation.

Industry feasibility issues test whether the recommendations are realistic in view of normal industry goals and behavior. Technological exchange with a government agency is not an everyday course of affairs for most American businesses. Government and industry have different goals. One seeks to make money, while the other has its imperatives laid out in the U.S. Constitution. While some adaptation on the part of industry will be required, the less NASA's programs conform to regular industry practices, the less chance the agency has of succeeding in maintaining an effective relationship. A successful program should recognize and help bridge the gap between industry and government. It should offer incentives for industry participation, and it should take into account any potential difficulties with such problems as antitrust and conflict of interest.

These issues--antitrust and conflict of interest--are a reminder that NASA and industry operate in an environment of public policy constraints. One prominent source of explicit constraints is the nation's legal system, which establishes boundaries for cooperation among companies, defines patent rights, regulates commerce and so on. A prominent source of implicit (and sometimes, explicit) constraints is the political environment, a network of

elected and appointed officials who watch and judge a government agency's actions. Appendix E examines seven areas of public policy concern: tax policy, regulatory policy, patent policy, antitrust policy, policy regarding access to government-held information, organizational conflict of interest issues, and R&D support. These concerns are considered appropriate in screening the options.

Public policy issues, particularly those which are politically based, have potential to change over time. The fourth category of screening criteria considers this eventuality by taking into account future-oriented issues.* These concerns are the most difficult to define, but they are vital to long term planning. Changes in the political environment, economic trends, and future foreign competition may have a bearing on technology transfer, and anticipating these effects is an important step toward coping with them.

All four categories of screening criteria are not applicable to each recommendation. Whereas NASA feasibility is a hurdle each recommendation must overcome, public policy and future-oriented issues are of less importance to some of the recommendations. One reason for this is that some issues are more internally than externally focused and thus will have little intercourse with NASA's operating environment. Also, some of the recommendations call for less significant change than others, and these will raise fewer screening issues than the more substantial recommendations. In the following discussion, screening criteria are considered as appropriate for the recommended actions.

*See Appendix K, The Future Environment for Technology Transfer.

Screening the Recommendations

1. Focus the coordination of technology transfer activities in NASA by creation of a new position at the Associate Administrator or Associate Deputy Administrator level.

This recommendation raises significant issues in terms of NASA feasibility. In particular, the action would require substantial organizational change, as well as a reallocation of resources, and it may meet with internal resistance from NASA personnel. Despite these potential barriers, the action is worth taking for the following reasons:

- It would signal NASA's commitment to technology transfer.
- It would provide technology transfer with prestigious spokesmen within NASA and on Capitol Hill.
- It would promote industry contact by creating a logical liaison at NASA for senior corporate officials.

Creating a new administrative position is not an innovative or unusual idea, but as a course of action, it is fundamental to legitimating technology transfer within the agency. By appointing an official at this level with technology transfer as his sole mission, NASA would confirm that it is serious about technology exchange. The new administrator would be responsible for providing direction, overcoming obstacles to new ventures, attracting personnel and defending his budget before OMB and the Congress. Without such leadership, technology transfer is likely to languish at NASA.

Whether this office were supported with new funds or a reallocation of existing funds, internal personnel may regard it as an encroachment on their own resources and authority. In the zero sum game of government agency budgets and hierarchies, creation of a new high level position represents an intrusion on existing domains. Yet it is just this type of action which signals a commitment to a change in policy. Once the office was created, it would be the new administrator's responsibility to ensure that technology transfer is not relegated to a backseat role in the organization.

This recommendation specifically addresses concerns for industry feasibility. By providing a liaison for senior corporate officials, it would help in bridging the gap between government and industry. While most technological exchange occurs at the lower, more technical levels of an organization, complications can arise which require senior level decision making. Under the present system, corporations dealing with NASA are not sure who makes final decisions for the agency. In negotiations on technology exchange, corporations need to know where the buck stops, and they do not want to thread their way through a bureaucratic maze to obtain a decision. An Associate Administrator for technology transfer would provide an authoritative, visible contact for corporations needing timely answers.

Public policy issues are bound to arise when private companies and government agencies exchange information, and as changes in these areas of concern occur, changes in policy will be necessary. One of the new administrator's primary roles would be to deal with these issues, whether it involves making a decision on conflict of interest, acting as a lobbyist on Capitol Hill, or redirecting the technological focus of transfer activities. A personal, full-time commitment to dealing with these issues would improve the agency's ability to handle them.

The qualities needed for success in this job include those typically associated with effective leadership in government: managerial expertise, skill in dealing with Congress and OMB, and knowledge of the subject area. Furthermore, it is essential that the Associate Administrator have familiarity with business practices and needs and experience in dealing with senior corporate officials.

One danger associated with this recommendation is that the administrator would become too authoritative. In his efforts to promote technology transfer, he may overcentralize the function. Technology transfer should have its focus at the Field Centers. The new administrator should recognize that his is a support function, consisting of policy making, final decision making and program advocacy. Efforts to direct the daily business of transferring technology could stultify activities in the Field Centers.

One step toward implementing this recommendation would be to form a search committee to identify candidates for the job. The committee should be small, consisting of three to five members, with at least one representative from the Technology Utilization Program and one or more from industry. In addition to identifying job candidates, the committee may provide input on the costs and organizational details associated with opening a new office.

2. Delegate technology transfer activities to the Field Centers.

Technology transfer cannot be accomplished from Washington alone. More often than not, those who recognize the applicability of NASA technology and work at adapting it to their needs are working level corporate engineers in various locations around the country. It is essential that NASA have the capacity to take the technology to them, and that it be able to provide the kind of person-to-person contact that is essential to overcoming application obstacles. These needs argue for a dispersed effort, where responsibility for transfer is in the hands of mobile NASA engineers. Each of the Field Centers should develop a client base and familiarize itself with the needs of the businesses in its area. While support and guidance from Washington are essential, the individual transfers are most likely to be accomplished through an on-going, personal approach in the field. Prolonged contact and easy accessibility are crucial qualities for the Field Centers to possess.

Thus, this recommendation is targeted toward industry concerns. It is offered in recognition that most companies will not come to Washington in search of new technologies, nor are they likely to respond to broadcasts of information from NASA Headquarters. In terms of NASA feasibility then, the crux of this issue is to balance decision making at Headquarters with autonomy in the Field Centers. As noted above, the Field Centers should bear responsibility for the daily business of initiating and carrying out transfers. The new Associate Administrator should operate in a staff capacity, providing support and guidance to the Field Centers, acting as a source of final authority and decision making when necessary, and providing a central NASA focus for relations with other Executive Branch agencies, the Congress, and the public.

One problem with delegating authority to the Field Centers is that Headquarters loosens its control of public policy issues. While Headquarters can provide direction on such subjects as conflict of interest and patent rights, most of the daily decisions will be made in the Field Centers. Increasing Field Center autonomy thus heightens the possibility of conflicting policies or violation of directives from Headquarters. Without decision making in the Field Centers, however, the process of transferring technology is bound to become more cumbersome because of the lag involved in conveying information to Headquarters and receiving decisions.

This recommendation will require some redefinition of Field Center priorities. The Field Center personnel need to be made aware of their responsibility for technology transfer and offered rewards for their success. Field Center goals for technology transfer should be broad enough to allow for autonomy but specific enough to measure performance. NASA should strive

to establish an entrepreneurial spirit in the Field Centers, by increasing their responsibility, clarifying their goals, offering them rewards, and giving them leeway for accomplishing these goals.

Implementing steps for this recommendation include:

- Meeting with the Field Center Directors to emphasize the importance of technology transfer;
 - Establishing technology transfer goals for each Field Center;
 - Formulating an appropriate incentive system; and
 - Establishing a regular program of performance review.
3. Increase the allocation of resources (funding and manpower) to technology transfer activities.

Funding demonstrates commitment. In constant dollars, NASA's 1983 budget for the Technology Utilization Program was 64 percent of its 1980 budget--not a very convincing sign of commitment to technology transfer (see Appendix B). By increasing resources for enhanced technology transfer, NASA would demonstrate that the TU Program is more than a public relations effort. Increased funding would provide a means for experimenting with new programs, devoting more man hours to corporate contracts, traveling to more corporate sites, and devoting more resources to overcoming technology adaptation problems.

In terms of both NASA feasibility and public policy, increases or reallocation of resources would meet resistance within the agency and possibly on Capitol Hill. The Office of Management and Budget has not been supportive of past technology transfer activities, and resistance from this quarter and from Congress (other than the authorizing committee) can be expected if NASA requests more funds. On the other hand, if NASA reallocates its existing funds to expand technology transfer activities, it is fostering a zero sum game where one program benefits at the expense of others. Reallocation decisions are bound to meet with internal resistance.

One way of dealing with resistance on both these fronts is to emphasize the benefits to NASA of a technology transfer program. Technology transfer should be presented as a vehicle for exchanging and exploiting technology, not merely dispersing it.

Increasing resources for technology transfer raises the possibility of augmenting the existing program with new approaches. Without more money, the remaining avenue to expanding technology transfer would be to scuttle existing programs in favor of new experimental ones. As an extreme example, one alternative would be to close out the existing Technology Utilization Program and replace it with experimental efforts such as those suggested in this report. In terms of NASA feasibility, the organizational and managerial problems associated with scrapping an existing program in favor of a new one are self evident.

Industry feasibility and future-oriented issues are not of particular relevance to this recommendation. A few points are worth noting, however:

- By devoting more resources to technology transfer, NASA may convince some industry skeptics that the agency is interested in more than a public relations job.
- Future elections may change the budgetary picture for NASA, perhaps to the benefit of technology transfer.
- Future successes scored by foreign competitors at the expense of the U.S. may provide further evidence of the need for cooperation between American industry and government. This would create a favorable environment for increasing resources for technology transfer.

As an implementing step to increasing the allocation of resources, the administrator should increase funding for technology transfer as a percent of the total budget. Then, in hearings before Congress, NASA could request additional funding and point to its own resource allocations as evidence of its commitment to technology transfer. In other words, NASA could go to Congress requesting a matching funds type of arrangement.

4. Establish a technology transfer activity fund at each Field Center under the authority of the Center Director.

This recommendation addresses a need for internal incentives at NASA. As such, it does not pose significant problems in terms of industry feasibility, public policy, or future-oriented issues.

The activity funds should be disbursed to the Field Centers on the basis of performance in transferring technology. Some Field Centers may enjoy an advantage over others because of their areas of emphasis and geographic locations, but funding must be allocated to the proven performers in order to obtain the most effective return on the dollars spent. The Field Centers should have substantial flexibility on how the funds are used, and experimentation should be encouraged.

One of the managerial problems associated with this recommendation is the difficulty of measuring performance in transferring technology. Are some transfers more important than others or can the number of transfers simply be counted? What constitutes a successful transfer of technology? Given the vague nature of the process, a Field Center's performance in transferring technology must be determined largely on a judgmental basis. Quantitative measures of technology transfer simply may not be feasible. Nevertheless, certain measures can be used as indicators of performance. Such indicators include: number of potential clients contacted, number of documented cases of transfer, number of information requests received, and number of hours devoted to transfer activities. Field Center Directors should be required to document such measures when providing regular reports of transfer activities. Activity funds should be allocated on the basis of these reports.

One of the first steps toward implementing this recommendation would be to identify a source of funds. If additional funds are allocated to technology transfer, these may provide a source for Field Center activity funds. If no additional funds are allocated, some portion of Field Center funds needs to be designated as a discretionary pool for technology transfer activity funds. Based on their performance, Field Centers may receive more or less funds than they were receiving for TU activities.

A second implementing step would be to define the criteria to be used in determining how the activity funds will be allocated. Suggestions for these criteria have been provided above. A uniform but brief reporting format (both written and oral) needs to be established for Field Center Directors and regular reporting schedules established.

5. Establish a NASA-wide recognition program for extraordinary accomplishment in technology transfer activity.

NASA personnel tend to regard the Technology Utilization function as a peripheral activity whose contribution to NASA's mission is not self-evident. This recommendation addresses the need to reinforce management's greater emphasis on this function by providing the means by which to recognize accomplishments in technology transfer. By doing so, the agency conveys the message that technology transfer is an important activity for which exemplary performance will be recognized. Like the recommendation for establishing activity funds, this action addresses an internal need. It does not have significant ramifications in terms of industry feasibility, public policy and future-oriented issues.

In terms of NASA feasibility, the recommended recognition program raises the classic issue of managerial control. How can the rewards be formulated to make them valuable to the recipient? On what criteria should

the recipients be chosen? Given the difficulties of determining the extent of a particular transfer's benefits or the parties ultimately responsible for its successes, symbolic awards would be easier to administer than monetary ones, though the latter should not be precluded. The perceived value of these awards will depend on their position along a continuum of such factors as:

- many award recipients versus few recipients,
- recognition by the recipient's immediate supervisor versus recognition by a higher-level administrator,
- recognition in a letter versus recognition in an awards ceremony, and
- low level publicity versus wide-ranging publicity.

One way to enhance the status of the awards would be to encourage industrial clients to nominate award recipients. By involving industry in the recognition process, NASA would demonstrate that transferring technology involves making and sustaining external contacts. Success in transferring technology should be measured not just by NASA standards, but by industry standards as well.

Industry satisfaction should be one of the criteria for choosing the award recipient. Other criteria to consider may be expressed as questions:

- Did the potential recipient initiate the contact that led to transfer, or was he exceptionally responsive to a query from industry?
- Did the potential recipient take an innovative approach to transferring technology? What barriers did he overcome?
- What were the benefits of the transfer for industry and NASA?
- How widespread were the benefits of the transfer?
- Does this transfer offer potential avenues for future transfers?

The recognition program provides a vehicle for emphasizing that technology transfer is an agency-wide responsibility, applicable at all levels and involving not only NASA personnel, but those in universities and industry as well.

Implementing steps include:

- determining an appropriate form of recognition,
- establishing the criteria for recognition, and
- soliciting candidates through notification of appropriate industry, university and NASA personnel.

* * * * *

The five recommendations discussed above are components of a broader recommendation that NASA establish technology transfer as a vital activity of the agency. The next group of actions contributes to a second broad recommendation that NASA expand the channels of cooperation with industry.

1. Base cooperative efforts on areas of NASA technological strength or areas of special interest to NASA.

NASA should concentrate on the areas it knows best. These are the areas where it is most likely that NASA will have something of value to offer to industry. Recalling that technology transfer is a two-way process, NASA should concentrate in its own areas of special interest or need.

In terms of NASA feasibility, this means that the agency needs to conduct an inventory of its strengths and special interests. In order to be functional, this inventory must be brief--no more than a few pages long. Requiring brevity forces the agency to focus its efforts, and it provides industry with a quick, accessible introduction to NASA capabilities. In terms of industry feasibility, detailed backup information would be desirable, but a lengthy report of NASA's technological strengths is likely to go unread.

Interest in NASA technologies will vary according to industry needs and changes in the future environment. For example, renewed concern with energy shortages could rekindle interest in NASA's solar energy capabilities. The definition of NASA strengths may vary according to the perspective of industry engineers versus government scientists, or technical researchers versus marketing professionals. These dynamics argue for a continuing reexamination

of NASA's areas of emphasis in transferring technology. In defining its strengths for the purposes of technology transfer, NASA should consider not only what its most sophisticated technologies are but also what "sells."

Compiling such an inventory is a first step toward implementing this recommendation. The result of this effort should receive wide distribution.

2. Join with industry in industry/university consortia for research and technology exchange.

The advantage of industry/university consortia is that they provide a structure for uniting diverse groups in a mutual research effort. Participants have an opportunity to trade information while working toward a common end. One challenge in organizing these endeavors is to establish a framework which provides incentives for participation by all parties while maintaining the integrity of each.

For both NASA and industry, participation in consortia would involve new institutional relationships. Initializing and sustaining such relationships would require attention to a number of organizational details. For industry, the incentive to participate would be the opportunity to acquire knowledge that would be helpful in establishing a competitive edge--either through new products or new production processes. For NASA, the incentive would be not only the opportunity to acquire knowledge, but also the opportunity to transfer its own know-how. The critical ingredient to successful partnership is that both parties be convinced of the value of NASA's expertise. The consortia should focus on areas of NASA's technical strength.

In terms of public policy, antitrust issues may be of particular concern when several firms in the same industry join in a research consortium. Thus far, the Justice Department has exhibited tolerance for these types of arrangements. Conflict of interest and confidentiality issues may arise

out of the tension inherent in cooperative efforts between a private, competitive firm and a public agency. While NASA has an obligation to serve the general public, it risks undercutting the incentive for industrial participation if it precludes its partners from garnering a competitive advantage from the relationship.

The public policy problems inherent in new institutional relationships between government and industry may not be amenable to broadly formulated solutions. Rather, each situation may require its own adaptations or negotiated settlements.

Several factors are at work to make this an appropriate time for participation in industry/university consortia. The Justice Department has adopted a tolerant attitude toward cooperation; economic problems and foreign competition have fostered an awareness of the need for innovative approaches to maintaining competitive technologies; and a number of these consortia have been started in recent years.

One step toward implementation of this alternative would be to review the structure and performance of existing consortia in order to identify some guidelines for successful organization. Candidate universities and industries should be identified on the basis of mutual interests. Negotiations with these parties would need to address such areas as direction of research, conflict of interest, proprietary rights, costs, and commitments of personnel. A number of unexpected organizational details are likely to emerge. This suggests that a project manager should be designated who is responsible for researching the issue, initiating contacts, and hammering out the details of partnership. Without a project coordinator, who would provide a logical contact for industry and university participants, partnership in a consortium may never get off the ground.

3. Expand joint endeavor agreements beyond the current Materials Processing in Space Program.

The Materials Processing in Space Program (MPS) provides experience NASA can use in organizing future joint endeavor agreements. In terms of NASA and industry feasibility, the challenge is to foster programs which would generate rewards sufficient to justify the costs of participation, including the up-front costs of initiating and organizing the endeavor. Hammering out details on such topics as lines of communication, facility use, and personnel commitments may require a significant amount of time from NASA and industry.

Arrangements of this type generate a number of public policy concerns. In certain situations, it may appear that NASA, a government agency, is giving undue advantage to a private firm. On the other side, industry may have concerns about divulging proprietary information to a government agency. As noted earlier, issues of confidentiality, conflict of interest, patent rights and other public policy concerns may be more amenable to problem-specific solutions than to broad declarations of policy. Each decision will require that NASA weigh the need to offer industry incentives against the need to avoid an appearance of subsidizing a particular firm.

A first step toward implementing this recommendation would be to identify potential areas for joint endeavors. On the basis of this determination, firms could be identified which may have an interest in participating in the program. These efforts already are underway at NASA.

4. Bring industry representatives into NASA's technology planning process.

A precedent for this type of action was established by NACA when it embraced industry participation in aeronautical research planning. It is

recommended that industry personnel participate in technology planning, not in the more detailed concerns of daily business. Thus, the industry participants would act in a role comparable to that of a Board of Directors or consultants.

In terms of NASA feasibility, the primary concern will be to design the program and choose participants in such a way as to encourage constructive participation. NASA personnel may be prone to regard the industry representatives as distractions from their first order of business, particularly if the industry representatives appear ill-informed. Perhaps the best method to avoid this problem would be to begin by soliciting and accepting support only from individuals who have some familiarity with NASA and who possess demonstrated expertise in the relevant technologies.

The incentive to industry for participation would be the opportunity to improve familiarity with NASA, its technological needs and its technological capabilities. Participation could raise conflict of interest issues in that industry representatives might be pictured as directing NASA planning for their own corporate benefit. This issue may be diffused, but not avoided, by emphasizing broad, conceptual participation, rather than day-to-day, nuts-and-bolts participation, and by selecting participants on the basis of acknowledged technical expertise.

Bringing outsiders into NASA's technology planning would assist the agency in anticipating technological change. Industry representatives may be no better informed than government representatives, but they have a different network of contacts and interests. Their knowledge would supplement NASA's in identifying potential developments relevant to NASA technology.

Steps toward implementation include reviewing the NACA program for its pitfalls and successes and identifying candidates in industry for participation in the program.

5. Test the feasibility of encouraging engineers, representing industry, to search and assess NASA technology for applications.

Encouraging industry engineers to assess NASA technology for possible applications would substitute a "demand-pull" situation for the typical "technology-push" situation. Instead of having NASA promote its technology to them, the industry representatives would have the opportunity to initiate the process with their own needs foremost in mind. The essence of this recommendation is that industry has the best idea of what it needs. Thus, it is a recommendation formulated with industry feasibility in mind. The incentive to participate for industry is the opportunity to gain access to new technology.

This incentive raises familiar public policy issues. Would NASA be giving undue advantage to a private firm by allowing it to search NASA technology? Would this open-door policy accelerate the leakage of technological know-how to foreign countries? The questions are interrelated. NASA may avoid the appearance of favoring one firm at the expense of others if it opens its technology to all comers. By doing so, however, the agency weakens its ability to control the flow of information to foreigners.

It may be necessary to classify some technology as proprietary information. Beyond that, NASA should screen candidates according to their interests and expertise, but it need not make special efforts to be overly protective of access to its technology. One of the basic tenets of technology transfer is that technological advantages are gained through active exchange of information, not by harboring secrets.

In terms of NASA feasibility, there may be some resentment of industry engineers "intruding" to study and ask questions about NASA technology. The agency should limit these technology reviews to a reasonable number, and the candidate screening process should serve this purpose. Even with these limits, there may be some internal resistance to the program, but such a reaction seems an inevitable part of making technology transfer a vital (e.g., time-consuming) activity.

This recommendation would benefit NASA not only by facilitating technology transfer, but also by improving its industry contacts. These contacts would provide valuable information in terms of technological trends and industry needs and capabilities.

As steps toward implementing this recommendation, NASA needs to consider a number of procedural details. What technology is available for review? What form should the review take (literature searches, laboratory tours, engineering interviews, etc)? How should industry candidates be identified and screened? Each of these questions requires a working knowledge of how the agency functions, but none should constitute a significant barrier to implementing the recommendation.

6. Explore means to use industry-related publications as channels to publicize NASA technology.

NASA scientists and engineers cannot be blamed for seeking to publish only in the most prestigious journals. Unfortunately, these journals may not be the ones with the widest readership in industry. Simply publishing information does not constitute an active approach to technology transfer, particularly if the information is distributed in publications rarely read by industry. On the other hand, publishing in trade magazines and industry journals at least demonstrates an effort to concentrate on target markets.

In terms of NASA feasibility, several steps may be taken to encourage the use of these publications:

- Distribute a list of target magazines, along with information on how to submit articles, to NASA personnel.
- Offer recognition awards for articles receiving the widest distribution.
- Make publication in these magazines one criterion considered in performance review.
- Advertise NASA technology and publications in these magazines whether NASA articles are published in them or not.

While industry-related publications are an obvious form of dissemination, others should be considered as well. These include trade fairs, computer-based information banks, and new forms of information exchange made possible by advances in telecommunications. Organizing this effort and creating incentives for participation by NASA personnel are the major tasks to implementing this recommendation. Concerns for industry feasibility, public policy issues and future-oriented issues are relatively minor.

7. Review with the U.S. Air Force additional means to expand or assure NASA an aerospace industrial base.

Contracts are one of NASA's most powerful tools for transferring technology. Its contract specifications can foster innovation by requiring the contract recipient to either develop new technologies or adopt someone else's technology. Either way, a new technology is "transferred" to the contract recipient. By expanding its contractor base, NASA expands the field of recipients for these new technologies.

Air Force contractors provide a logical avenue for expanding this base since NASA and USAF have similar contracting needs. The Air Force can provide NASA with an expanded pool of recipients for requests for proposals. This recommendation offers no real difficulties in terms of the screening criteria and requires only some coordination with the Air Force in order to be implemented.

APPENDIX I

Case Studies of NASA-Industry Cooperation
in the Transfer of Technology

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Case Studies of NASA-Industry Cooperation in the
Transfer of Technology

The three short papers which follow are brief "case studies," limited to the systematic description of three examples in which NASA worked closely with representatives of industry to cooperatively push the frontiers of technology. Each, in a different way, provides an example of how technology has been transferred or shared.

Two, "Wind Tunnels," and "Crashworthiness Design Technology," are in aeronautics, while the third, "Goddard Battery Workshop," has its origins in a common space technology challenge. Each deals with a program that stretches over many years.

The first, "Wind Tunnels," exemplifies a special characteristic of NASA (and its precursor, NACA)--unique facilities and the capability to provide qualified staff for their operation and data reduction. The crashworthiness case study reflects a variety of cooperative means, based upon voluntary sharing, to meet common technical objectives. The battery conferences reveal how an ad hoc approach to dealing with a problem became regularized into a recognized, annual event.

These cases suggest the pervasiveness of opportunities for technology sharing and transfer between NASA and industry.

CASE STUDY: WIND TUNNELS

"The wind tunnel is indispensable to the development of modern aircraft. Today no aeronautical engineer would contemplate committing an advanced aircraft design to flight without first measuring its lift and drag properties and its stability and controllability in a wind tunnel. Tunnel tests first, free-flight tests later, is the proper order of things."¹

In 1908, Wilbur Wright startled the European aviation community by piloting his Flyer for a successful one and one-half hour flight. While the United States government had not purchased any sort of flying machine, by this time European countries began to pour major resources into aeronautical development, including wind tunnels. Between 1903 and the start of World War I, Europe had captured technical leadership in aviation. Centralized government-funded aeronautical laboratories were built in England, France, Germany, Italy and Russia. When the war began, France had 1,400 military aircraft; Germany, 1,000; Russia, 800; and Britain, 400. The U.S. flying machine inventory was 23.

NACA/NASA's Research Role

Prior to the end of the war, NACA began drawing plans for its first wind tunnel at Langley Field. The emphasis of this new course of action was based on the idea that, when the war ended, there would be classes of aircraft and trained personnel available for full operation. Also envisioned was a strong link to a new industry of plane-makers, since NACA had no intention of manufacturing aircraft. Ames and Lewis Research Centers both were placed close to the fledgling aviation industry sites in recognition of the twofold purpose of servicing the industry and learning from it.

Airfoil, or wing, research began as early as 1923 and, with the completion of the Variable Density Tunnel at Langley, has become one of the most fruitful and long-running programs. The VDT quickly established NACA as a technically competent research organization and witnessed all manner of aircraft from monstrous Zeppelins to military aircraft. An NACA Technical Report published in 1933 listed a total of 78 airfoil sections that were tested. This technical report eventually found its way into the

¹Baals, Donald D., and Corliss, William R. Wind Tunnels of NASA, Washington, D.C.: U.S. Government Printing Office, 1981, page 1.

designs of many successful aircraft companies' ships, e.g., the Douglas DC-8 transport, the Boeing B-17 Flying Fortress, and the famous Lockheed twin-tailed P-38. Airfoil design and analysis remain important areas in the changing designs of manufacturers today. On the west coast, the original Ames tunnel began in 1944 and has tested over 100 aircraft. Nearly anything that flies has been tested at Ames, including sleek jet fighters, cargo planes, helicopters, commercial airliners, and the space shuttle orbitor.

Coordinating Arrangements

In tracing progress of aerospace and aircraft industries over the past 65 years, it would be impossible to ignore the joint efforts of NACA/NASA and private industry. Each concern involved--whether it was the Air Force, Navy, Lockheed, Grumman, Bell, Rockwell, United Technology, McDonnell Douglas, Ames, Langley or Lewis--committed expertise, problems, time and money. According to the experience of Donald Baals, an aeronautical engineer with NACA/NASA for more than 40 years, each partner had a complementary function. As the aircraft industry developed, it was only natural that aircraft and NASA engineers worked together to transfer technical information and share facilities to lessen the financial burden of each. Baals remembers the 1940's as the most interesting and productive in that NACA often served as a catalyst and the most effective give and take of information occurred in a very short turn-around time.

During the First and Second World Wars, NACA and the armed forces were inevitable partners in problem solving. But out of these years rose the need for industry involvement in manufacturing engines, flight systems and the like. Agreements during this time included the exchange of personnel and technical data, access to use of facilities without charge, and publication of research papers. The aircraft industry did thrive despite the accessibility of confidential data, and out of these endeavors emerged monumental results. Research and development included countless areas of real concern--tail-spin recovery and life-saving parachutes, propeller and basic wing design for vertical and short takeoff and landing situations, retractable landing gears, wing and propeller icing, swept and delta wing evolution, laminar flow experimentation and full scale testing. Nearly every present-day aircraft was developed out of a need to assure predictability and performance. The industry began in the 1950's to exploit all of the wind tunnel theories towards the primary goal of manufacturing civil transports.

Currently at Ames, NASA and McDonnell Douglas are engaged in a project which is part of the Aircraft Energy Efficiency Program. This model jet engine simulation, conducted with the help of various other industries, will help aircraft designers develop jet transports that have less drag and are more economical to fly. NASA and Hamilton Standard are deep into a joint research program which will lay the groundwork for prop fan technology, as industry planners cannot ignore fuel prices and the depletion of natural resources. In the wind tunnel tests, the prop fan experiments are realizing an efficiency of 80 percent. The partnership that now exists between NASA and the aeronautics industry has evolved over two-thirds of a century. It is

a unique working relationship that is an exemplary procedure for effectively interacting with the private sector. It would be difficult to create such a relationship between the government and a mature industry today.

Current and Future Problem Areas

Today, despite the willingness to cooperate on everyone's part, cooperative agreements have turned into major undertakings. Wind tunnel facilities have become more than major in size, as of course have their capacities. This has created problems. It is difficult to schedule time and/or facilities. NASA is also limited by budgets and a pressing need to cover all operational costs. A "sales job" approach, wherein a company pays for tunnel time, is often advantageous in recouping ongoing operational costs. The space program has also occupied in-house testing time.

It is of course an advantage to have one's own wind tunnel--an idea followed by many aircraft manufacturers, such as Boeing, Lockheed, North American Rockwell and McDonnell Douglas. Often these companies do routine testing in their own facility and return to Ames, Langley, and Lewis to complete and/or verify their own findings.

Tracing specific involvements over time appears to be next to impossible due to personnel turnover, records retrieval problems, the number of facilities involved and time lapsed. Lee Stollar, Deputy Director of Aeronautics at Ames, estimates that cooperative efforts involve perhaps 33 percent of operations time at that facility today. Most often, a private company, the military and NASA invest equal time and resources.

Conclusion

In 1980, 60 U.S. aviation experts assembled at the National Academy of Sciences Study Center in Woods Hole, MA, for the purpose of determining NASA's future role in aeronautics. One of the three major conclusions of the workshop exemplifies opinions of those mentioned above:

"The close and successful working relationship that was initiated in 1915 between the National Advisory Committee for Aeronautics. . . and the fledgeling aviation industry and has continued uninterrupted to its present mature state under. . . NASA must be strengthened and maintained. The present relationship is unique in the United States and stands as an example of effective cooperation between government and industry, which is particularly important in light of the current concern with developing a cooperative and supportive relationship between government and industry. Contrary to a view widely held by many sectors of private industry that there should be little or no government involvement in their affairs, the various sectors of the aviation industry that were represented. . . clearly

endorsed the present NASA-industry working relationship. The key point here is that government cooperation. . . can have a stimulating and strengthening effect on an industry that will enable it to compete more effectively in the international marketplace and prevent its vulnerability to foreign trade offensives."²

References

Baals, Donald D., and Corliss, William R. Wind Tunnels of NASA, Washington, D.C.: U.S. Government Printing Office, 1981.

National Academy of Sciences. NASA's Role in Aeronautics: A Workshop (Vol. I, Summary), Washington, D.C.: National Academy Press, 1981.

Telephone conversation with Donald D. Baals, Retired NASA Astronautical Engineer, Newport News, VA.

Telephone conversation with Lee Stollar, Deputy Director of Aeronautics, Ames Research Center, Moffett Field, CA.

²National Academy of Sciences. NASA's Role in Aeronautics: A Workshop (Vol. I, Summary), Washington, D.C.: National Academy Press, 1981, page v.

CASE STUDY: CRASHWORTHINESS DESIGN TECHNOLOGY

In 1972 Langley Research Center in cooperation with the FAA and industry began a program to develop technology for improved crashworthiness and occupant survivability in general aviation aircraft. The ongoing program includes formal contract relationships as well as informal exchanges of information with the FAA (Research Center in New Jersey and Civil Aero-medical Institute in Oklahoma) and several industrial entities. The effort includes analytical and experimental work and structural concept development. Crashworthiness design technology is divided into three areas addressed by both Langley and the FAA but, due to the nature of each agency's designated functions within the government, their tasks vary.

Under the general area of environmental technology, Langley acquires actual crash data, through records voluntarily submitted by air carriers and from its own crash tests, to use in prototype development; the FAA, as a regulatory agency, evaluates quantitative crash data to define a crash envelope. Concerning the second area --airframe design--Langley conducts full scale crash tests, develops and validates advanced analytical techniques, and conceives and evaluates concepts for future designs of airframes; the FAA assesses current analytical technology. Finally, under component design technology, Langley develops all aspects of cabin interiors and the FAA evaluates seats and restraint systems.

The flow of information between NASA and the FAA appears to be open and easy. Each critiques the other's work and joint contracts are sometimes let. Both agencies often participate in the same government, industrial and association conferences which reinforces each group's understanding of the other's work and needs. There are, however, minor barriers to a totally satisfactory relationship. One official at Langley related a perceived "sluggishness" in the setting of regulations at the FAA. Another source related that the Army requires more stringent safety precautions in its helicopters than does the FAA. But, because personnel at Langley work closely with both the FAA, which regulates, and with industry, which bears the expense of any regulations, they are careful to "walk a fine line" between them by remaining neutral and presenting information only and by not making any recommendations regarding those regulations.

Langley and Private Industry

Researchers at NASA and in private enterprise stress the importance of working openly with peers. Personal communication is considered important to avoid misinterpretations. But in so estoric an endeavor as flight safety which is based on mathematics and physics, it is sometimes difficult to find others with enough of the same background and understanding with whom to easily communicate. Most of Langley's activities, therefore, have been in the nature of sharing information rather than mutual participation on particular projects. In many instances there is no formal contract established between the entities. Both NASA, with its vast facilities such as wind tunnels

and laboratories, and industry, with the ability to provide test items such as seats and other equipment, find it mutually beneficial to foster informal avenues of cooperation. The following case studies exemplify the results of such cooperation.

1. Grumman Aerospace Corporation

A close relationship has existed between Grumman and Langley for approximately 15 years. Both entities work on crashworthiness but NASA is evidently at the forefront of research because Grumman has conducted its work "almost as an adjunct to Langley's efforts." Besides mutually exchanging information, Grumman has been a NASA contractor. One of the better known projects done under NASA contract is DYCAST, a computer program which simulates crashes of planes, helicopters or even automobiles. The Grumman program is based on a Langley concept and was returned to Langley where it was refined and applied to vast amounts of crash data in order to further understand impact phenomena. It was also used at Langley to simulate tests of load limiting substructures (floors). The benefits to NASA and the FAA are in eventual increased aviation safety. Grumman benefits by being able to use the program for its own research and as a consulting tool which it will market to automobile, helicopter, and aircraft companies. DYCAST was prereleased to interested companies and individuals for evaluation. In its final form it will be disseminated through COSMIC, and Grumman will continue to privately sell courses and consulting on the program's specific uses. Personnel at Grumman consider the NASA relationship of prime importance and stated a willingness to give NASA projects top priority in task assignments.

2. Mooney Aircraft Corporation

Mooney Aircraft personnel had been studying laminar flow dynamics. When it was noticed that there were small inconsistencies between the results they were getting and NASA's data, Mooney researchers went to Langley to learn more about the problem. They explained everything they had done and NASA agreed to investigate the same area. Later, Mooney subcontracted to a research center at Texas A&M for further work and no formal contract was ever negotiated with Langley. In relation to the Crashworthiness Program, researchers at Mooney "simply became friendly with people at Langley working in the same area." Again there was no particular project, but each visited the other's facilities. Since the issues involved were so complex, the contact at Mooney estimates that it took about a year to establish effective communications between the company and Langley.

Some of the specific ways in which Mooney and Langley have shared expertise are: Mooney used NASA research data in air flow research for development of its air foil; Mooney gave NASA results of wind tunnel tests which led to insights into prediction of crashworthiness; Mooney will give full scale verification of results gained from a new plane on which Mooney has worked for four years and will soon test. There are no formal contracts for any of these arrangements.

3. Bell Helicopter

Langley and Bell "shared and looked at concepts together" to get ideas for civil aircraft. For the last test, Langley used one of Bell's experimental seats. The two groups shared all available engineering data. There was no contract involved.

4. Boeing, Lockheed and McDonnell Douglas

Sometimes a way can be found to transfer information even though one or more of the participants is reluctant. Such was the case when Langley requested crash data from Boeing, Lockheed and McDonnell Douglas for the period 1959-1979. Aircraft manufacturers are extremely sensitive to the possibility of litigation over past accidents and none cared to be singled out. Langley was aware of this, and the request was worded so that the companies knew that only accident trends were to be studied and not specific crashes or specific carriers. The companies complied, went through their own files to preserve confidentiality, and were entitled to all information derived from the study.

5. Ford Motor Company

Although not part of the Crashworthiness Program, another type of "partnership" is exemplified by NASA and Ford. Ford Motor Company provided test vehicles for noise reduction studies and was given test data to further its own research.

Conferences

Langley Research Center actively participates in industrial and association conferences and, of course, holds many seminars and workshops of its own. At the workshops, small groups of research peers are invited to attend and interact. All participants seem to freely share their most current data.

A formal conference was recently held jointly by NASA and the AIAA (American Institute of Aeronautics and Astronautics). The attendees were principally members of nonaerospace industries from the Fortune 1000. Speakers were from Langley, Lewis, Ames and Headquarters. The topic was Advanced Materials Technologies. Participants were encouraged to interact with the agency representatives and among themselves. "Partnership" arrangements are expected to spinoff from these meetings.

The Society of Automotive Engineers (SAE) has provided a well respected forum for the presentation of Langley papers (as well as others) and for the exchange of information among all researchers interested in aviation. Langley reports much of its seat and substructure work here.

The EAA (Experimental Aircraft Association), directed by Paul Poberezny, is the largest experimental aviation group in existence. The purpose of its meetings is the open ended transfer of technology. Attendees include researchers, manufacturers, and government agency personnel.

NASA and the Radio Technical Commission for Aeronautics (RTCA)

The RTCA is a nongovernment organization looking at problems in aviation. It is funded by the FAA. Langley is assisting the RTCA by studying in depth a problem with the reliability of emergency locator transmitters. Information is being provided by every segment of the aviation community. The investigating committee, called Special Committee - 136, is chaired by Dr. Robert Thomson of Langley. Langley is demonstrating ELT sensor activation problems by mounting ELT specimens in full-scale crash test aircraft as well as conducting other tests. Other members of RTCA will provide data from actual crashes and non-distress activation.

Barriers and Incentives

Very few barriers to cooperative efforts are evident from the interviews made for this report. Contacts frequently stressed the benefits to all concerned in being able to openly discuss and share data with others in the field of crash dynamics. There do not seem to be many problems with proprietary information since, in one contact's words, "What happens is that details of specific research are sufficiently complex that only researchers on the problem at the moment are able to understand it. Details of the mathematics and testing are so precise that, unless one has been working for some time on it, the information would not be useful. Anyone else might as well wait for the information to be published." However, the esoteric nature of the technology may make current methods of scientific exchange less than efficient. In so highly technical a field as crash dynamics, researchers must often spend a great deal of time searching for other individuals working on exactly the same problem and using similar approaches. In general, though, it was felt that an imposed systematized method of technology transfer would shut off needed creativity and openness of contacts. One contact also expressed concern that management tends to simplify transmission of technology and needs to work more closely with their research people to better understand the intricacies involved.

Perhaps a more concrete barrier is industry's fear of litigation. Aircraft manufacturers, for instance, fear regulations made by the FAA but they are also reluctant to make changes through their own research because they may be held responsible for not making them sooner, especially if it could be shown that injury occurred because of lack of innovation. Consequently they must be dealt with sensitively by NASA.

References

Hayduk, Robert J., Robert G. Thomson, and Huey D. Carden. NASA/FAA General Aviation Crash Dynamics Program--An Update, Langley Research Center. Presented at the Annual Seminar, International Society of Air Safety Investigators, Montreal, September 24-27, 1979.

Telephone conversation with Stan Miller, T.U. Officer at Ames Research Center, Palo Alto, CA, on 10/17/82.

Telephone conversation with John Samos, T.U. Officer at Langley Research Center, Hampton, VA, on 10/17/82.

Telephone conversation with Huey Carden, Engineer-Inventor at Langley Research Center, Hampton, VA, on 10/30/82.

Telephone conversation with David Peake, Research Assistant at Ames Research Center, Palo Alto, CA, on 11/18/82.

Telephone conversation with Dwight McSmith, Supervisor Engineer at Langley Research Center, Hampton, VA, on 11/19/82.

Telephone conversation with Robert Thomson, Program Director at Langley Research Center, Hampton, VA, on 11/24/82.

Telephone conversation with Alan Pifko of Grumman Aerospace Corp., Long Island, NY, 12/1/82.

Telephone conversation with Fen Taylor Chief of Aerodynamic Performance and Special Projects, Mooney Aircraft Corp., Kerrville, TX, on 12/3/82.

CASE STUDY: GODDARD BATTERY WORKSHOP

Background and Format

In 1968 a two-day review was held at Goddard Space Flight Center to determine why cells in the battery of an orbiting astronomical laboratory had failed a performance test. Those involved were battery users from industry and government and the manufacturer of the cells in question. Two things became apparent: first, that the manufacturer was reluctant to share proprietary production information and, second, that attendees had not previously had such an opportunity to communicate with each other. To alleviate the latter problem and to increase efficiency and lifetime of spacecraft battery systems through exchange of information between users and manufacturers, the first formal annual Battery Workshop was held at Goddard in 1969.

Each year the workshop is announced in publications such as Advanced Battery Technology and Batteries Today. Invitations are sent to the Electrochemical Society and a mailing list of 600 interested people amassed over the years. Participation is open to all including battery users, manufacturers, and researchers from industry, government, and academia; foreigners must have clearance to attend. At the 1981 workshop 222 individuals attended from the following types of organizations: 24 different battery manufacturers, 22 battery users, 17 government and military agencies, 11 universities and consulting firms, and 25 other types.

The workshop is oriented to emphasize problem solving and getting results. Unlike a conference or symposium, the intent is not to make formal presentations of dated material but to bring notes and visuals describing up-to-the-minute progress. Free-wheeling discussion and intercommunication are considered of prime importance. Failures and problems are verbally communicated which would not have been admitted to in formal papers.

Originally, the number of presentations was limited and length of discussion sessions was not. NASA used a court reporting service to provide verbatim transcripts of the sessions. However, more and more people requested time to give reports; some had to present a paper or they couldn't come. To allow for this and yet not curtail discussion time, the workshop was lengthened from two to three days around 1973. At about the same time NASA started producing the proceedings as a conference publication, which are available through Scientific Technical Aerospace Reports (STAR) and Selected Current Aerospace Notices (SCAN).

The first workshop topic was nickel cadmium batteries; nickel hydrogen batteries were included in the mid-1970's and lithium in the late 1970's. Time had to be made available as each topic was added. Over the years, the format has been altered to optimally accomodate both freewheeling discussion and prepared presentations. The workshop is now a combination of panel sessions, paper presentations, and question/answer periods.

It normally costs \$25,000 to put on a workshop, including a court reporter at \$8,000-\$10,000 taping, word processing, typing, reviewing, etc. Funding for the 1982 workshop was cut to \$7,000-\$8,000.

The workshop is unique in the industry. An Electrochemical Society conference requires reports to be submitted 6-9 months before presentation. Because of the workshop's informal format and no prior clearance requirement, a person can show up on the day of a session and present yesterday's results. Quality of presentations and visuals may not be uniformly high due to the lack of screening, but this drawback is more than compensated for by the catalytic stimulation of ideas.

As an annual affair, the workshop has established a feeling of continuity and camaraderie throughout the industry. The pattern of communication and information sharing that has been produced otherwise wouldn't exist. While year-round communication within the industry has been enhanced by contacts made at the workshops, what occurs at a workshop cannot be duplicated. The variety of ideas presented within those three days brings the overall picture of a development's status into focus in a way two people can never approach. The feedback a manufacturer gets en masse at a workshop may be considered more valuable than individual customer complaints.

Participants

The workshop is directed by the battery users, from both government and industry. They candidly describe their experiences with the manufacturers' products, including test results as well as actual performance successes and failures. Manufacturers basically listen to this feedback, taking the problems raised back to their own laboratories to examine in greater detail. While discussion of performance can be very specific--for example, pinpointing exactly where a leak occurs in a certain battery and under what conditions--the discussion does not go into production methods that may have resulted in the leak, as such methods are considered proprietary by the manufacturer. Users' comments are limited to government programs for which test results are available and public information; testing for the commercial sector is considered proprietary.

This protective behavior of manufacturers creates some problems but does not critically limit what the workshop accomplishes. Manufacturing techniques may not be presented at the workshop but users are familiar with them from close association with particular manufacturers. Users must be careful during the workshop, therefore, to not reveal such information to competitors.

The role of academic researchers is somewhat unclear. Because the workshop is engineering oriented little effort is made to present theoretical research, which some perceive as a weakness. To others, the academicians attending have had a limited "hands on" experience and are there to learn about the "real world"; their interests, such as how to design an electrode, are not suitable workshop topics but they contribute during discussions of basic concepts.

Technology Transfer

Workshop topics and the problems discussed are geared toward aerospace applications from NASA and unclassified Air Force programs. Aerospace batteries and terrestrial batteries do differ. Whereas a car battery is said to be "flooded," space batteries operate in a "starved" system, i.e., there is no electrolyte solution in a space battery because fluid in space separates into droplets. Space batteries have to be efficient, reliable, and durable for a number of years. These qualities and ancillary improvements in testing and storage are applicable to terrestrial batteries as well.

Working with batteries for space involves a different philosophy from batteries for use on earth, however. Batteries for space are produced in small quantities and each must be 100 percent reliable, whereas terrestrial batteries are produced in large numbers and the goal is to make a large percent of those produced highly reliable.

Cost is the major barrier to technology transfer. The cost to make a high-quality aerospace battery is of little concern when it means a satellite either works or doesn't. The consumer, however, will not pay for the quality required to make a battery last ten years; a less than 100 percent reliable battery is perfectly acceptable.

Such marketing dictates are joined by other evidence of lag in the application of innovative aerospace technology to terrestrial batteries. Manufacturers, having already made a big capital investment in production methods, are reluctant to make the changes necessary to produce, e.g., the improved electrochemically made positive electrodes introduced at the workshop.

Aerospace battery technology transfer exemplifies that impediment to transfer in which the users may identify the benefits of a new technology but its implementation gets delayed in the commercial sector, where the costs and benefits of adopting the new technology are weighed differently.

As far as dissemination of information beyond the workshop is concerned, there is no indication that the proceedings themselves have much of an impact on the industry. No other specific NASA documentation, such as Special Publications or Technical Support Packages, have resulted from workshop activity. SP's, TSP's, and other relevant NASA documents are made available during the workshop.

Benefits

The workshops have proved beneficial to participants who have neither the time nor other resources required to collect the same amount of information provided in one three-day period. Airing problems that aerospace engineers have with batteries helps to avoid pitfalls, educates inexperienced and junior level people, and provides a mechanism for obtaining help with potential problems. The exposure and give-and-take afforded by the workshop setting promotes changes and lessens the impact of a new technology, although it is impossible to determine to what degree.

Over the years batteries have become more reliable and reproduceable, partly because of workshop feedback. In the aerospace industry, improvements in battery production have meant marked savings. For example, the need for duplicate testing has been eliminated. Aerospace contractors used to buy 3-4 times as many cells as necessary--enough for testing and selecting matched cells for the flight set. The battery manufacturer's test data were unreliable, so the aerospace contractor did its own testing; such duplicate testing is very costly. Due to improvements in manufacturing, reproduction, and selection, the aerospace contractor no longer has to conduct tests.

Another example of how the workshop has benefitted battery technology is accelerated aging testing. The industry can't afford to wait ten years testing a battery that is supposed to last ten years; battery testing must be done as fast as possible. This demands the development of accelerated aging techniques that will yield the same data as real time testing. Accelerated aging procedures are still being formulated and discussions over the years at the workshop have contributed to improving the methodology.

Other specific benefits attributed to the workshop are a better definition of reconditioning, better thermal control, and the general shift toward use of electrochemically made positive electrodes.

References

NASA Press Release No. 76-200, "Space Battery Workshops Pay Double Dividends," December 8, 1976.

Conversations with Gerald Halpert, technical staff, Space Power Applications Branch, Goddard Space Flight Center, and Battery Conference Chairman, August 18, 1982, September 10, 1982, and March 21, 1983.

Conversation with John W. Lear, Program Management Developer, Martin Marietta Aerospace, Denver, CO, September 16, 1982.

Conversation with Dean W. Maurer, Supervisor of Nickel Cadmium Battery Development, Bell Telephone Laboratories, Murray Hill, NJ, October 25, 1982.

Conversation with Guy G. Rampel, Manager of Aerospace Engineering, GE Corp., Gainesville, FL, October 27, 1982.

APPENDIX J

Illustrations of Industry/University Consortia

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and
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ILLUSTRATIONS OF INDUSTRY-UNIVERSITY CONSORTIA

As part of NASA's effort to expand the channels of cooperation with industry, DRI has recommended that the agency join with industry, universities and research laboratories in consortia for research and technology exchange. This attachment provides an introduction to existing industry/university consortia by providing examples of various types of consortia and an indication of their funding levels. This information demonstrates some of the alternatives available to NASA and provides a starting point for investigating the feasibility of NASA participation.

Between 1975 and 1982, industry funding for university research climbed from less than \$100 million to more than \$200 million. By 1990, industry funding could be as high as \$600 million.¹ Cooperative efforts between Carnegie-Mellon and Westinghouse, Massachusetts General Hospital (Harvard) and Hoechst A.G., and Washington University and Monsanto are well-publicized examples of the increasing number of industry/university consortia. These consortia may take a variety of forms, several of which are discussed below.

Centers of excellence. In consortia of this type, industry funds are used to establish university research centers which address topics of interest to industry. An example is provided by the Semiconductor Research Cooperative (SRC) which is a subsidiary of the Semiconductor Industry Association. SRC is soliciting corporate contributions of at least \$50,000 in an effort to build an annual budget of \$40-50 million. With this money, SRC plans to establish 8 to 10 "centers of excellence" beginning with a

¹"Colleges, Firms Discuss Conflicts of Industry-Backed Research," Argus Leader, 19 December 1982, Section F, p. 2.

joint project between the University of California at Berkeley and Carnegie-Mellon and another project at Cornell University. Both of these centers will be working in the area of computer-aided design.²

Special state funds may be earmarked to support centers of excellence. In Arizona, for example, the state has assisted Arizona State University in establishing the Center for Engineering Excellence. Of nearly \$30 million projected to underwrite the new center, the state is supplying \$20 million, with industry contributing the remainder; construction of microelectronic and computer laboratory facilities is under way.

University-sponsored liaison programs. The Industrial Liaison Program (ILP) at the Massachusetts Institute of Technology (MIT) provides an example of this type of program. Each company belonging to the program has a liaison officer to assess company interests and needs. The officer tries to match these needs with services provided by ILP. This program is passive in the sense that transfer is accomplished by review of current MIT research problems and new ideas, review of MIT publications and member attendance at symposia and seminars. Any research work on specific problems a company might have would be referred to a faculty consultant. Over 270 companies belong to the program, including 40 companies in Europe and 30 in Japan.³

University/industry cooperative centers. In the early 1970s, the National Science Foundation (NSF) launched the Experimental R&D Incentives Program to provide startup funds for research programs which have matching industry support. The MIT-Industry Polymer Processing Program was begun in 1973 on

²"Industry Invests In Research Centers," High Technology, May 1983, p. 15.

³The Industrial Liaison Program of the Massachusetts Institute of Technology (brochure presented by MIT), April 1981, no pagination.

this basis. Today, the MIT program is fully supported by a consortium of 12 industrial firms which pay an annual fee depending on the firm's size.

The Experimental R&D Incentives Program has evolved into the University-Industry Cooperative Research Centers Program. This program is part of NSF's Innovation Processes Research Section under the Division of Industrial Science and Technological Innovation (ISTI). The program has provided startup funds for nine university research efforts.

One of these is the Rensselaer Polytechnic Institute's Center for Interactive Computer Graphics. Formed in 1977, the Center had an operating budget of \$620,000 in 1982, which included \$480,000 in industry support. Companies contribute about \$20,000 annually to become "Industrial Associates"; these funds are used to support graduate students and research staff. The Industrial Associates are involved in setting guidelines for selection of research projects concentrating on interactive computer graphics and CAD/CAM projects.⁴

Besides the MIT Polymer Processing Program and Rensselaer's Center for Interactive Computer Graphics, there are seven other programs partially funded by NSF:⁵

⁴Development of University-Industry Cooperative Research Centers: Historical Profiles, ed. J.D. Eveland and William Hetzner, Innovation Processes Research Section, National Science Foundation, May 1982, p. 75.

⁵James D. Bruce, "University-Industry Interactions, The M.I.T. Experience," paper presented to the International Association of Consultants in Higher Education in Essex, United Kingdom, Sept. 13-15, 1981, no pagination.

Sponsoring University	Program Name
University of Massachusetts	Center for U-Mass/Industry Research in Polymers
Ohio State University	Center for Welding Research
Case Western Reserve University	Center for Applied Polymer Research
North Carolina State University	Cooperative Research Center for Communications and Signal Processing
Rutgers University	Ceramics Cooperative Research Center
Iowa State University	Advancement of Building Technologies

Source: NSF

These programs are not limited to those initiated with government funding. The University of Illinois, for example, established a Fracture Control Program nearly ten years ago, based upon cooperative funding and information interchange with interested industry. Representatives of participating companies attend semiannual briefings, consult with faculty, and exchange data and research results. Faculty may visit plants, collect operating information, and even run cooperative tests or other procedures. Information is shared, first, within the consortium of participants, then with the wider community.

Issues in industry/university consortia. The types of consortia discussed above exemplify an increasingly common arrangement: a research center which combines the facilities and expertise of universities with the expertise and financial capabilities of industry. The following consortia may be able to provide valuable information on how these arrangements work, their strengths and weaknesses, and how NASA can participate:

<u>Sponsoring University</u>	<u>Program Name</u>
Washington University	Center for Biotechnology
Massachusetts Institute of Technology	Laboratory for Manufacturing and Productivity
Stanford University	Center for Integrated Systems (CIS)
Arizona State University	Engineering Excellence for the 80s
University of Minnesota	Microelectronics and Information Sciences (MEIS)
North Carolina State, University of North Carolina/Chapel Hill, North Carolina A&T	Microelectronics Center of North Carolina
Massachusetts Institute of Technology	Polymer Processing Program
University of Michigan	Center for Robotics and Integrated Manufacturing (CRIM)
University of Rhode Island	Robotics Center
Carnegie-Mellon University	Robotics Institute

Source: "Industry Invests in Research Centers," High Technology, May 1983, p. 17.

With the proliferation of industry/university consortia, several recurring issues have emerged. One is what to do about patents and licensing. The emerging consensus seems to be that the universities retain patent rights to all new items produced, and the companies involved in the relationship automatically have non-exclusive royalty-free licenses. Any non-member companies who wish to use the patent must pay for the non-exclusive license and the royalty income is retained by the university. In cases where the companies are involved with a university on a very limited membership program, an exclusive license would be granted to the company involved and any royalty income would be shared.

It is necessary for both sides to compromise in order to meld the objectives of the academic community with the shorter-term profit objectives of the business community. In the area of publications, the general agreement seems to be that publication of information sponsored by industry is usually held back for a few months to allow company review. This seems to be done on the basis of "reasonable" time periods rather than by any set guidelines. The fear that close university/industry relationships will hamper academic and intellectual freedom and curtail basic research in favor of more applied projects seems to be growing stronger. The "profit" motive is not seen as an appropriate posture for a university. To take that suggestion further, Dr. James Bruce of MIT's Industrial Liaison Program states that starting university/industry collaboration programs with the intent of raising money for the university will cause eventual failure. In his experience these programs must be service-oriented with a stated purpose of increasing transfer of technology.⁶

Industry/university consortia appear to have a number of benefits. They provide hands-on experience for graduate students and an opportunity for participating companies to look over prospective employees. The research findings may contribute to the strength of a company, an industry, or the economy as a whole. Technology transfer is accelerated. These benefits, of course, will be weighed against the costs of participation--costs which may be measured in terms of dollars, academic freedom, threats to proprietary information, patent rights, and other factors. Whether the trend toward starting and operating these consortia will continue to grow will depend on the performance of existing institutions in dealing with these issues.

⁶ Ibid.

APPENDIX K

The Future Environment for Technology Transfer

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THE FUTURE ENVIRONMENT FOR TECHNOLOGY TRANSFER

The purpose of this review is to examine possible shifts in the future environment for their potential impact on NASA's efforts to enhance technology transfer. Three areas of concern are reviewed: the economy, foreign competition, and the political environment. Future developments in these areas are uncertain, but the types of developments discussed below appear reasonably likely to occur. The justification for discussing these developments and not others is that these are particularly relevant to technology transfer.

The Economy

Possible developments. There is a consensus that the U.S. is shifting from a manufacturing to a service-based economy. In the manufacturing sector, high technology industries may prosper while the smokestack industries continue to decline. These transitions may be characterized by a period of difficult adjustment, marked by such problems as structural unemployment, labor shortages in some high technology industries, and controversies over the allocation of capital.

Evidence of these problems is widespread. While the nationwide unemployment rate remains high, the unemployment problem is particularly acute along the Ohio Valley and other old industrial areas in the country. Automotive and steel workers who have been laid off are only beginning to realize that their jobs may be permanently lost. While some may seek to retrain themselves, frustration and despair may be more widespread reactions, particularly if retraining programs are unavailable or ineffective in placing their graduates in jobs. The result may be the emergence of a large group of structurally unemployed workers who constitute a drag on the economy and a source of political discontent.

Meanwhile, there is concern that the country will lack sufficient numbers of engineers and technical people to sustain the growth of high technology industries. The problem is self perpetuating. As the supply of engineers dwindles in relation to demand, the starting salary for engineers climbs. Universities find it more difficult to compete with industry salaries, and as a result, fewer engineers choose to pursue advanced degrees and careers in teaching. With fewer engineering teachers, the supply of well trained engineers declines even further.

Concern over capital allocation is evident in current controversies over the federal deficit and the perceived need for a national industrial policy. It appears that substantial amounts of capital will be needed to finance the national debt. As a result, many economists theorize that competition for capital will increase, interest rates will rise, and many private firms, particularly small businesses, may find themselves unable to afford new debt.

One of the central issues in the industrial policy debate concerns the allocation of capital among declining smokestack industries and rising high technology industries. The federal government has contributed to capital formation for ailing companies in order to save jobs. Actions such as the Chrysler loan guarantee have been criticized for supporting declining industries when government aid should be targeted toward stimulating growth industries. As the decline of smokestack industries and rise of high technology industries continue, it is likely that there will be calls for government aid to both sectors.

Implications for NASA. Conventional wisdom has it that growing economies provide the best environment for technology transfer. When economic conditions are good, capital is available for new ventures, and businesses

are more willing to take the risks associated with innovation. Future economic dislocations, as evidenced in high interest rates and low profits, may discourage business from adopting new technologies.

On the other hand, the need for new technologies may be most evident during times of economic distress. The recent proliferation of innovative institutions for performing research (such as industry-university consortia) may be attributable to the widespread perception that conventional R&D efforts are inadequate. The successes of foreign competitors (discussed below) and continuing economic problems at home have forced businesses to consider new ways of achieving and maintaining a technological edge. Such an environment would be conducive to NASA's technology transfer efforts.

Future economic developments should shape NASA policy, and the way NASA presents that policy, in several ways. First, NASA should demonstrate a willingness to participate in innovative ventures between government and industry. If economic dislocations continue, and institutions such as industry-university consortia enjoy some success, acceptance of these and similar institutions may spread. If NASA has demonstrated its competence in these types of arrangements, the growing interest in these institutions may generate interest in cooperation with NASA as well.

Second, NASA may be able to capitalize on the interest in a national industrial policy and gain more funding for technology transfer. After all, NASA's efforts do represent cooperation between government and industry, and they do provide a means of maintaining America's technological edge. NASA's technology transfer program offers the allure of high technology and innovative cooperation without raising the explosive issue of competition between declining and growing industries. Thus, technology transfer offers the government an opportunity to attack economic problems

in a noncontroversial way. NASA technology is a resource this country underutilizes. Making better use of this resource could be an acceptable component in a variety of otherwise dissimilar industrial policy options.

Third, NASA should monitor the economy in order to better understand its industrial clients. Lay-offs, the cost of capital, and shortages of engineering talent are daily concerns for many businesses. By improving its understanding of these concerns and the related needs and opportunities, NASA improves its ability to sustain a cooperative relationship with industry.

Foreign Competition

Possible Developments. Japan's economic success, much of it gained at the expense of American industry, has led to an increased awareness of the challenge posed by foreign competition. With the growing industrial strength of other foreign countries, particularly in the Third World, it is likely that intense foreign competition will characterize the future economic environment. This trend is discussed at length in "Factors Enhancing the Competitive Posture of Foreign High Technology" (Appendix C). The result of this competition is likely to include the three effects discussed below.

First, foreign competition may exacerbate problems in the U.S. economy. Competition from countries with low-cost labor and relatively modern manufacturing plants may continue to erode the economic base of older American manufacturing industries. Furthermore, competition from technologically advanced economies with strong government support (e.g., Japan) may lower the growth potential for American high technology industries.

Second, America may respond to this competition with protectionist measures. Specifically, imports may be curtailed or subjected to tariffs, and exports of American technology may be more strictly controlled. A "fortress" mentality may emerge whereby America seeks to maintain a

technological edge by guarding technological secrets. Such a policy would be particularly applicable to technologies with real or perceived value to national security. The threat of leaking sensitive technologies to adversary nations may lead to further efforts to restrict technology transfer.

Third, America may follow the example of its foreign competitors by adopting a more comprehensive national industrial policy. Such a policy would include closer cooperation between government and industry, probably influencing the future direction of research and development and capital allocation. Given this country's tradition of free enterprise, such a policy undoubtedly would be tempered by a concern for maintaining some distance between government and industry.

Implications for NASA. The implications of economic dislocations and attempts to design a national industrial policy have been considered above. Efforts to reduce technological leaks could have (already appear to have had some) negative consequences for NASA's technology transfer program. These efforts are bound to create barriers to technology transfer, either by requiring various forms of personnel and technology clearance or by precluding certain technologies from transfer altogether. Furthermore, a rising concern with technological leaks could foster distrust of the technology transfer program regardless of the kinds of technologies transferred. With foreign competitors benefiting from adaptations of U.S. technologies, any program which publicizes technology could be subject to criticism. Isolated instances of foreign countries using NASA technology could lead to a backlash against the entire program.

The problem could become more acute if NASA becomes more "militarized" in the future. Greater use of the space shuttle or other NASA technology for defense purposes raises a concern for guarding NASA secrets from

adversary nations. This concern may lead to a policy of "erring on the safe side," whereby most or all NASA technology is restricted from transfer.

It is helpful to distinguish between commercial technologies and those which are vital to national security. Protecting the former is a difficult and often fruitless business. If technologies are used on a commercial basis, it is difficult to restrict access to these technologies. Sooner or later, foreign competitors are likely to acquire these technologies through product purchases, literature reviews, professional conferences, informal conversations, industrial espionage or some other means. Funds devoted to restricting this process may be better spent developing new technologies that will contribute to America's technological lead. In the future, NASA should present its policy as one which contributes to economic progress and point out the futility of protecting most commercial technology.

Guarding technology which is vital to national security is a more legitimate and feasible concern. These technologies are fewer in number and have a narrower distribution than commercial technologies. If NASA becomes more "militarized," it may be expected to help protect military secrets. The agency has little choice but to acquiesce to this concern. NASA can continue to pursue transfer of nonsensitive technologies however.

The Political Environment

Possible developments. Trends in current politics may be noted, but these are subject to rapid change. Perhaps the only safe assumption is that national elections and congressional budget hearings will occur with predictable regularity. The timing of these events provides a framework for NASA planning purposes, and their outcome provides an indicator of prevailing attitudes toward NASA technology transfer.

One current trend in politics is increased support for various forms of research and development. As discussed in Appendix E, the Justice Department has demonstrated an apparent willingness to relax antitrust regulations in favor of joint endeavors for R&D. Federal spending for basic research is rising. New tax laws designed to facilitate capital formation may make the implementation of innovative technologies easier in the future.

Another political trend is toward decentralization in government. Explanations for this trend may be found in the "New Regionalism," which lowered levels of federal aid to state governments, as well as in other causes:*

- Prolonged economic stagnation has fostered disillusionment with federal macroeconomic policy.
- The spread of corporate headquarters and manufacturing centers has led to a realignment in the economic standing of the nation's regions.
- The "war on poverty" programs have fostered a number of active locally based economic development programs.

One aspect of this trend may be that states will take a stronger role in regulating technology. Recent efforts to formulate state policies regulating hazardous waste and nuclear power may be harbingers of an effort to tighten local control over potentially dangerous technologies.

A more widespread aspect of the "new regionalism" is increased competition between the states for new industry. Various states have adopted a range of approaches to luring and fostering industry. These include tax breaks, new business "incubation" centers, and industry-university research consortia. The states may take the lead from the federal government in implementing comprehensive industrial policies.

* See "The New Regionalism," National Journal, 21 May 1983.

Implications for NASA. The current attitude toward R&D provides a favorable climate for adopting new technology and pursuing technology transfer. If this attitude prevails, NASA should continue to pursue innovative R&D arrangements. Decentralization of technology regulation may pose new barriers to technology transfer, but only for those technologies which are potentially dangerous. Business competition among the states may foster interest in certain states for cooperating with NASA in joint research efforts.

In general, a pro-business attitude currently prevails in American politics. Continuation of this attitude would support NASA's efforts to increase cooperation with industry. Some conservative resistance to government-industry cooperation may arise out of concern that technology transfer or cooperation represent governmental interference in the free market. The success or failure of current innovative efforts may determine the strength of this resistance.

By committing itself to cooperation with industry and by enhancing its technology transfer efforts, NASA will be in a position to benefit from increased receptivity to government-industry cooperation. The economy, foreign competition, and political trends provide evidence this receptivity may continue to grow.

PART III

BIBLIOGRAPHY

NASA Partnership With Industry:
Enhancing Technology Transfer

Bibliography

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BIBLIOGRAPHY

- Abelson, Philip H., "Employment of engineers and scientists," Science, 216, June 11, 1982, p. 1.
- Adelson, Marvin. The technology of forecasting and the forecasting of technology. Santa Monica, CA: System Development Corporation, April 1968. Paper prepared for CENTURY-21: Human Values in a Technological Society lecture series, Stanford University, Palo Alto, California, April 25, 1968.
- Alexander, Arthur J. The linkage between technology, doctrine, and weapons innovation: Experimentation for use. Santa Monica, CA: RAnd, 1981.
- Amann, Ronald and Julian Cooper. Industrial innovation in the Soviet Union. New Haven, CT: Yale University Press, 1982.
- American Society of Mechanical Engineers. Federal technology transfer: Results of a survey of formal programs. New York: 1975. [75-WA/Aero-4]
- Arthur D. Little, Inc. Barriers to innovation in industry: Opportunities for public policy changes. Washington, DC: National Science Foundation, 1973.
- Arthur D. Little, Inc. Factors related to the implementation and diffusion of new technologies. A pilot study. Cambridge, MA: June 1979. [NTIS: PB-298998]
- Arthur D. Little, Inc. Federal funding of civilian research and development. Boulder, CO: Westview Press, 1976.
- Arthur D. Little, Inc. Passing the threshold into the information age: Perspective for federal action on information. Volume I: Basic findings report. Cambridge, MA: January 1978. [NTIS: PB-281720]
- Ault, Leonard A. and W. Novis Smith, eds. Federal R&D and scientific innovation. Washington, DC: American Chemical Society, 1979.
- Ayres, Leonard P. The economics of recovery. New York: Macmillan, 1933.
- Baer, Walter et al. Analysis of federally funded demonstration projects. Santa Monica, CA: Rand, 1976.
- Baer, Walter. Analysis of federally funded demonstration projects: Executive summary. Santa Monica, CA: Rand, 1976.
- Baker, Dale B., "Communication or chaos?" Science, 169, August 21, 1970, pp. 739-742.
- Beaumont, C., J. Dingle, and A. Reithinger, "Technology transfer and applications," R&D Management, 11:4, October 1981, pp. 149-155.

- Benjamin, John S. and Peter Hydrean. The effect of the time value of money on business decisions to fund R&D. Working paper prepared for submission to the Subcommittee on Space Science and Applications, Committee on Science and Technology, U.S. House of Representatives, on the Space Industrialization Act of 1979.
- Benjamin, John S., "Statement of Dr. John S. Benjamin, Research Manager, INCO Research and Development Center, INCO, United States, Inc., before the Subcommittee on Space Science and Applications, Committee on Science and Technology, United States House of Representatives on the Space Industrialization Act of 1979."
- Benton, Lewis R., ed. Private management and public policy: Reciprocal impacts. Lexington, MA: Lexington Books, 1980.
- Bergen, S.A., "The R&D/Production interface--United Kingdom and West German practices and achievements in the scientific instrument industry," R&D Management, 12:1, January 1982, pp. 27-36.
- Berman, Larry. The Office of Management and Budget and the Presidency, 1921-1979. Princeton, NJ: Princeton University Press, 1979.
- Black, Guy. Some effects of federal procurement of research and development on industry. Washington, DC: George Washington University, Program of Policy Studies in Science and Technology, 1968.
- Boffey, Philip M., "Pressures are increasing for arms race in space," New York Times, October 18, 1982.
- Bok, Derek C., "Universities and the new national effort," Science, 213, August 28, 1981, pp. 980-982.
- Booth, James and Zena Cook. An exploration of regulatory incentives for innovation: Six case studies. Washington, DC: Public Interest Economics Center, 1979. [NTIS: PB-299006]
- Botkin, James, Dan Dimancescu, and Ray Stata. Global stakes: The future of high technology in America. Cambridge, MA: Ballinger Publishing Co., 1982.
- Bowering, David J. and John K. Sheehan. Research study of the direct and indirect effects of federally-sponsored R&D in science and engineering at leading research institutions. Vol. II. Final report. Washington, DC: Science Management Corporation, November 1981. [NTIS: PB82-239328]
- Braden, Patricia L. Technological entrepreneurship: The allocation of time and money in technology-based firms. Ann Arbor, MI: University of Michigan, Graduate School of Business Administration, 1977.
- Braumstein, Yale M., William J. Baumol, and Edwin Mansfield, "The economics of R&D," in B.V. Dean, ed. Management of research and innovation. New York: North-Holland, 1980.

- Brodley, Joseph F., "Joint ventures and the Justice Department's antitrust guide for international operations," The Antitrust Bulletin, 24, Summer 1979, pp. 337-356.
- Bunten-Mines, Elaine, Julie Menke and Carl W. Shepherd. Cooperative R&D programs to stimulate industrial innovation in selected countries. Washington, DC: U.S. Dept. of Commerce, Office of Productivity, Technology and Innovation, June 1980.
- California Institute of Technology, Division of the Humanities and Social Sciences. Government policies and technological innovation. Pasadena, CA: undated.
- Carpenter, Mark. Ten year trends in U.S. technological dependence on foreign science and technology as indicated by referencing from U.S. patents. Phase I report. Cherry Hill, NJ: Computer Horizons, Inc., June 1981. [NTIS: PB82-146176]
- Carter, Charles, ed. Industrial policy and innovation. London: Heinemann, 1981.
- Cetron, Marvin J. and Harold F. Davidson. Industrial technology transfer. The Netherlands: Noordhoff International, 1977.
- Chalk, Rosemary. Notes on the NAS Report "Scientific Communication and National Security". Cambridge, MA: Massachusetts Institute of Technology, Program on Science, Technology and Society, undated (1982?).
- Chaplin, George, "A partnership under competitive stress," East-West Perspectives, 3:1, Summer 1982, pp. 35-40.
- "Chief of shuttle program hits industry preparation," Aviation Week and Space Technology, May 10, 1982, pp. 49-51.
- Collins, Eileen L. Tax policy and investment in innovation: A colloquium held April 24, 1981. Washington, DC: National Science Foundation, 1982.
- Commission of the European Communities. Transfer and exploitation of scientific information. Proceedings of the Symposium held in Luxembourg on June 10-12, 1981. Luxembourg: 1981. [NTIS: PB83-121921]
- Contractor, Farok J. International technology licensing: Compensation, costs, and negotiation. Lexington, MA: Lexington Books, 1981.
- Cordes, Joseph J., et al. The impact of tax and financial regulatory policies on industrial innovation. Washington, DC: National Academy of Sciences, 1980.
- Crowell, Eldon H., "The organizational conflict of interest--What is it and why is it? What is or should be considered an unfair competitive advantage?" Paper prepared in connection with the American Bar Association National Institutes, April 21-22 and May 11-12, 1977.

- Culliton, Barbara J., "The academic-industrial complex," Science, 216, May 18, 1982, pp. 960-962.
- Culliton, Barbara J., "Monsanto gives Washington U. \$23.5 million," Science, 216, June 18, 1982, pp. 1295-1296.
- Culliton, Barbara J., "Parajo Dunes: The search for consensus," Science, 216, April 9, 1982, pp. 155-158.
- Dean, Burton V., and Joel L. Goldhar. Management of research and innovation. New York: North Holland, 1980.
- Dearing, Charles L., et al. The ABC of the NRA. Washington, DC: The Brookings Institution, 1934.
- deLeon, Peter. The evaluation of technology R&D: A continuing dilemma. Santa Monica, CA: Rand, 1981.
- Denver Research Institute, University of Denver. Federal incentives for innovation: The impact of EPA administrative practice on the innovation process in U.S. companies--A case study of regulatory barriers to innovation. Denver, CO: January 1976.
- Denver Research Institute, University of Denver. Federal incentives for innovation. Part I: Guidelines for planning. Part II: The innovation process in the private and public sectors. Denver, CO: November 1973.
- Diebold, William. Industrial policy as an international issue. New York: McGraw-Hill, 1979.
- Dietrich, J.J. and R.K. Sen, "Making industry-university-government collaboration work," Research Management, 24:5, September 1981, pp. 23-25.
- Dixon, Robert, "Hybrid corn revisited," Econometrica, 48:6, September 1980, pp. 1451-1461.
- Doctors, Samuel I. The role of federal agencies in technology transfer. Cambridge, MA: M.I.T. Press, 1969.
- Doctors, Samuel I. Technology transfer by state and local government. Cambridge, MA: Oelgeschlager, Gunn & Hain, 1981.
- Donlan, Thomas G., "Yen for productivity: An inside view of why Japan Inc. works," Barron's, August 2, 1982, p. 28+.
- Dupree, A. Hunter. Science in the federal government: A history of policies and activities to 1940. New York: Harper and Row, 1957.
- Eads, George and Richard R. Nelson, "Government support of advanced civilian technology: Power reactors and the supersonic transport," Public Policy, 19:3, Summer 1971, pp. 405-427.

Early, Steve, "Unions and management in Europe seek to ease transition to new technology," Transatlantic Perspectives, 6, February 1982, pp. 20-24.

Edwards, George C. Implementing public policy. Washington, D.C.: Congressional Quarterly Press, 1980.

"Europe: A search for ways to close the technology gap," Business Week, December 21, 1981, pp. 52-53.

Eveland, J.D., et al., eds. Development of university-industry cooperative research centers: Historical profiles. Washington, DC: National Science Foundation, 1982.

Ewing, Ky P., "Joint research, antitrust, and innovation," Research Management, 24:2, March 1981, pp. 25-29.

Fay, Richard J. Program for the exploitation of unused NASA patents. Third annual report. Denver, CO: University of Denver, Dept. of Mechanical Sciences and Environmental Engineering, 1971. Also Second annual report, 1970.

Flaherty, Robert J. "Harris Corp.'s remarkable metamorphosis," Forbes, 125, May 26, 1980, pp. 45-48.

Ford, David and Chris Ryan, "Taking technology to market," Harvard Business Review, 59:2, March/April 1981, pp. 117-126.

Foster, Richard N. "A call for vision in managing technology," Business Week, May 24, 1982, pp. 24+.

"France: An electronics plan with global ambitions," Business Week, May 31, 1982, p. 39.

Fusfeld, Herbert I., Richard N. Langlois, and Richard R. Nelson. The changing tide: Federal support of civilian-sector R&D. New York: New York University, Center for Science and Technology Policy, 1981.

Geren, Gerald S., "Some effects of antitrust and tax policies on R&D," Industrial Research and Development, 24:2, February 1982, pp. 49-50.

Gerstenfeld, Arthur. Technological innovation: Government/industry co-operation. New York: John Wiley & Sons, 1979.

Gilmore, John S., et al. The channels of technology acquisition in commercial firms, and the NASA dissemination program. Washington, DC: National Aeronautics and Space Administration, June 1967. Prepared by the Denver Research Institute.

Gilmore, John S., et al. Defense industry diversification: An analysis with twelve case studies. Washington, DC: U.S. Arms Control and Disarmament Agency, January 1966. Prepared by the Denver Research Institute.

- Gilmore, John S., John J. Ryan, and William S. Gould. Defense systems re-sources in the civil sector: An evolving approach, an uncertain market. Washington, DC: U.S. Arms Control and Disarmament Agency, July 1967. Prepared by the Denver Research Institute.
- Ginsburg, Douglas H., "Antitrust, uncertainty, and technological innovation," The Antitrust Bulletin, 24, Winter 1979, pp. 635-686.
- Ginsburg, Douglas H., et al. Antitrust, uncertainty, and technical innovation. Washington, DC: National Academy of Sciences, 1980.
- Gold, Bela, Gerhard Rosegger, and Myles G. Boylan. Evaluating technological innovations: Methods, expectations, and findings. Lexington, MA: Lexington Books, 1980.
- Gold, Bela. Productivity, technology, and capital: Economic analysis, managerial strategies, and government policies. Lexington, MA: Lexington Books, 1979.
- Grabowski, Henry G., et al. The impact of regulation on industrial innovation. Washington, DC: National Academy of Sciences, 1979.
- Gregory, Gene, "Japan's industrial revolution," The Futurist, August 1982, pp. 30-32.
- Griliches, Zvi, "Hybrid corn: An exploration in the economics of technological change," Econometrica, 25:4, October 1957, pp. 501-522.
- Griliches, Zvi, "Hybrid corn revisited: A reply," Econometrica, 48:6, September 1980, pp. 1463-1465.
- Griliches, Zvi, "R&D and the productivity slowdown," American Economic Review, May 1980, pp. 343-348.
- Gruber, William H., "The science-technology-utilization relationship in management," Management Science, 21:8, 1975, pp. 956-963.
- Hadden, Susan G., "Scientific data and public policy; A review of The Scientific Basis of Health & Safety Regulation," Science, 216, April 30, 1981, pp. 508-509.
- Halloran, Richard, "U.S. plans big spending increase for military operations in space," New York Times, October 17, 1982.
- Harvard Business Review. The management of technological innovation. Cambridge, MA: Harvard Business Review, 1982.
- Harvard University, Center for International Affairs. Program on U.S.-Japan relations. Annual report, 1980-81. Cambridge, MA: 1981.
- Hawken, Paul, James Ogilvy, and Peter Schwartz. Seven tomorrows: Towards a voluntary history. New York: Bantam Books, 1982.

- Hayes, Robert H. and David A. Garvin, "Managing as if tomorrow mattered," Harvard Business Review, May-June 1982, pp. 71-79.
- Hayes, Robert H. and William J. Abernathy, "Managing our way to economic decline," Harvard Business Review, 58:4, July/August 1980, pp.67-77.
- Hermann, Robert J. USDRE independent review of DoD laboratories. Washington, DC: Undersecretary for Defense Research and Engineering, March 22, 1982. [NTIS: AD-A118006]
- Herrmann, John F, "Redefining the federal government's role in technology transfer," Research Management, 25:1, 1983, pp. 21-24.
- Hill, Christopher T. and James Utterback, eds. Technological innovation for a dynamic economy. New York: Pergamon Press, 1979.
- Hoffman, Joel E., "Joint industry research and other cooperative programs: Antitrust hazards and lawful opportunities," Food Drug Cosmetic Law Journal, 32, October 1977, pp. 444-458.
- Holliday, George D. Technology transfer to the USSR, 1928-1937 and 1966-1975: The role of western technology in Soviet economic development. Boulder, CO: Westview Press, 1979.
- Holloman, J. Herbert. Technical change and American enterprise. Washington, DC: National Planning Association, 1974.
- Hydreon, Pete. The effect of time and reasonable tax law improvement on the recouping of R&D and plant expenditures. Suffern, NY: The INCO Research and Development Center, 1979.
- Iizuka, Akio, "The spirit of harmonious competition," Technology Review, August/September 1982, pp. 53-54.
- Industrial Research Institute, Inc. Institutional and legal constraints to cooperative energy research and development. Washington, DC: U.S. Dept. of Commerce, March 1975. Prepared for the Commerce Technical Advisory Board. [NTIS: PB-240929]
- Irvine, John, et al. Government support for industrial research in Norway: A SPRU report. Brighton [U.K.]: University of Sussex, July 1981.
- "Japan's strategy for the '80's," Business Week, Special issue, December 14, 1981, pp. 39-120.
- JWK International Corporation. Benefit assessment of NASA space technology goals. Final report. Annandale, VA: July 1976. Prepared for the National Aeronautics and Space Administration.
- Johnson, Chalmers. MITI and the Japanese miracle: The growth of industrial policy, 1925-1975. Stanford, CA: Stanford University Press, 1982.

- Jones, Dorothy E., "Crying wolf over a threat from Asia," Business Week, July 26, 1982, pp. 6-7.
- Kahn, Herman. The coming boom. New York: Simon and Schuster, 1982.
- Kaplan, Eugene J. Japan: The government-business relationship. Washington, DC: U.S. Dept. of Commerce, 1972.
- Kaplan, Robert S. Tax policies for R&D technological innovation. Washington, DC: National Science Foundation, March 1976.
- Kierulff, Herbert E., "Business venture development and evaluation," Reprint from Journal of Business, undated.
- Klein, Frederick C., "Circuit breakers: Reverse engineering of microchips is slow, costly--and universal," Wall Street Journal, August 5, 1982.
- Knight, Kenneth E., George Kozmetsky, and Helen R. Baca. Industry views of the role of the federal government in industrial innovation. Austin, TX: University of Texas at Austin, 1976.
- Kolata, Gina, "How can computers get common sense?" Science, 217, September 24, 1982, pp. 1237-1238.
- Krosin, Kenneth E., "Joint research ventures under the antitrust laws," George Washington Law Review, 39, July 1971, pp. 1112-1140.
- La Fleur, James K. The R&D limited partnership: A financial breakthrough for inventors and small businesses. Los Angeles, CA: 1980.
- Ladenburg, Art. Impact of the Freedom of Information Act on the national intelligence agencies. Carlisle Barracks, PA: U.S. Army War College, 1982.
- Landro, Laura, "GE promotes factory automation, but some doubt big market exists," Wall Street Journal, October 21, 1982.
- Lederman, Leonard L., "Federal policies and practices related to R&D/innovation," Research Management, 21:3, May 1978, pp. 18-20.
- Lehner, Urban C., "Hitachi still feels blow to its reputation," Wall Street Journal, July 20, 1982.
- Lewis, Jordan D., "Technology enterprise, and American economic growth," Science, 215, March 5, 1982, pp. 1204-1211.
- Lundstedt, Sven B. and E. William Colglazier, eds. Managing innovation: The social dimensions of creativity, invention, and technology. New York: Pergamon Press, 1982.
- Magat, Wesley A., "The effects of environmental regulation on innovation," Law and Contemporary Problems, 34, Winter/Spring 1979, pp. 4-25.

- Magee, James D., et al. The National Recovery Program. New York: F.S. Crofts and Co., 1933.
- Mansfield, Edwin, "Basic research and productivity increase in manufacturing," American Economic Review, 70:5, December 1980, pp. 863-873.
- Mansfield, Edwin, "Contribution of R&D to economic growth in the United States," Science, 175, February 4, 1972, pp. 477-486.
- Mansfield, Edwin, Anthony Romeo, and Samuel Wagner, "Foreign trade and U.S. research and development," Review of Economics and Statistics, 61:1, February 1979, pp. 49-57.
- Mansfield, Edwin, "How economists see R&D," Harvard Business Review, 59:6, November/December 1981, pp. 98-106.
- Mansfield, Edwin. Industrial research and technological innovation: An econometric analysis. New York: W.W. Norton, 1968.
- Mansfield, Edwin, "The process of technical change." In Richard A. Tybout, ed., The economics of research and development. Columbus, OH: Ohio State University Press, 1965.
- Mansfield, Edwin, et al. The production and application of new industrial technology. New York: W.W. Norton, 1977.
- Mansfield, Edwin, "Research and development, productivity and inflation," Science, 209, September 1980, pp. 1091-1093.
- Mansfield, Edwin, et al. Research and innovation in the modern corporation. New York: W.W. Norton, 1971.
- Mansfield, Edwin, "Tax policy and innovation," Science, 215, March 12, 1982, pp. 1365-1371.
- Mansfield, Edwin. Technological change. New York: W.W. Norton, 1971.
- Mansfield, Edwin, "Technology and technological change." In John H. Dunning, ed., Economic analysis and the multinational enterprise. London: George Allen and Unwin, Ltd., 1974.
- Mathematica, Inc. Quantifying the benefits to the national economy from secondary applications of NASA technology. Washington, DC: National Aeronautics and Space Administration, June 1975.
- McEachron, Norman B., et al. Management of federal R&D for commercialization. Menlo Park, CA: SRI International, 1978. [NTIS: Vol. 1=PB-292852; Vol. 2=PB-292853]
- McGrath, Phyllis S. Redefining corporate-federal relations. New York: The Conference Board, 1979.

- McGuire, E. Patrick. Spin-off products and services: The commercialization of internally supported resources. New York: The Conference Board, 1976.
- Mechlin, George F. and Daniel Berg, "Evaluating research--ROI is not enough," Harvard Business Review, 58:5, September/October 1980, pp. 93-99.
- Miller, Hugh P. and Rolf R. Piekarz. Technology, international economics and public policy. Boulder, CO: Westview Press, 1982.
- Mogavero, Louis N. and Robert S. Shane. What every engineer should know about technology transfer and innovation. New York: Marcel Dekker, 1982.
- Morton, Jack A. The innovation process. Bell Telephone Laboratories, undated.
- Mueller, Dennis C., "Research and development costs as a barrier to entry," Canadian Journal of Economics, No. 4, November/December 1969, pp. 570-579.
- Mulkey, Michael A. and Roland G. Weiss. Prospects for an OSHA/ETIP project to facilitate technological innovation. Washington, DC: U.S. Dept. of Commerce, National Bureau of Standards, 1980.
- Naisbitt, John. Megatrends: Ten new directions transforming our lives. New York: Warner Books, 1982.
- National Academy of Engineering. Industrial innovation and public policy options. 2 vols. Washington, DC: National Academy Press, 1980.
- National Academy of Engineering. Technology transfer and utilization: Recommendations for redirecting the emphasis and correcting the imbalance. Washington, DC: 1974.
- National Academy of Engineering and National Research Council. The competitive status of the U.S. auto industry: A study of the influences of technology in determining international industrial competitive advantage. Washington, DC: National Academy Press, 1982.
- National Academy of Sciences. Applied science and technological progress: A report to the U.S. House of Representatives, Committee on Science and Astronautics. Washington, DC: Government Printing Office, June 1967.
- National Academy of Sciences, Committee of Science, Engineering, and Public Policy. Research briefings for the Office of Science and Technology Policy, the National Science Foundation, and selected Federal departments and agencies. Washington, DC: National Academy Press, 1983.
- National Academy of Sciences. Scientific communication and national security. Washington, DC: National Academy Press, 1982.
- National Aeronautics and Space Administration. NASA Program Plan: Fiscal years 1981 through 1985. Washington, DC: January 1980.

- National Aeronautics and Space Administration. Private sector involvement in the NASA Technology Utilization Program. Report to the U.S. House of Representatives, Committee on Science and Technology, and the U.S. Senate, Committee on Commerce, Science, and Transportation, February 1982.
- National Research Council. Risk and decision making: Perspectives and research. Washington, DC: National Academy Press, 1982.
- National Science Foundation. Proceedings of a Conference on Technology Transfer and Innovation. Washington, DC: 1967.
- National Science Board. University-industry research relationships: Myths, realities, and potentials. Washington, DC: National Science Foundation, 1982.
- National Space Club. Presentations from the National Space Club Conference June 1982.
- National Technical Information Service. Technology transfer: General and theoretical studies, 1981 - February 1982. Citations from the NTIS data base. Springfield, VA: 1982. [NTIS: PB82-806001]
- National Technical Information Service. Technology utilization: Application of aerospace technology, 1970 - July 1982. Citations from the NTIS data base. Springfield, VA: 1982. [NTIS: PB82-869751]
- Nations, Richard, "The high-tech hijack," Far Eastern Economic Review, July 2, 1982, pp. 72-77.
- Nelkin, Dorothy, "Intellectual property: The control of scientific information," Science, 216, May 14, 1982, pp. 704-708.
- Nelson, Richard R, "In search of useful theory of innovation," Research Policy, 6:1, January 1977, pp. 36-76.
- Norman, Colin, "Electronics firms plug into the universities," Science, 217, August 1982, pp. 511-514.
- Nelson, Richard R., Merton J. Peck, and Edward D. Kalachek. Technology, economic growth and public policy. Washington, DC: The Brookings Institution, 1967.
- Norris, William C. Rebirth of technological innovation via small business. Place?: Control Data Corporation, 1979. Address given to the American Physical Society.
- Old, Bruce S. Return on investment in basic research--Exploring a methodology. Concord, MA: Bruce S. Old Associates, Inc., 1981.
- Organisation for Economic Cooperation and Development. Innovation in small and medium firms. Paris: 1982.

Organisation for Economic Cooperation and Development. Innovation policy: Trends and perspectives. Paris: 1982.

Ouchi, William G., Jay B. Barney, and Dave Ulrich. Program for research on organizations and management: The United States-Japanese electronic industries study. Interim report. Los Angeles, CA: University of California at Los Angeles, Graduate School of Management, August 1981. [NTIS: AD-A118106]

Overmeer, W. and F. Prakke. Government procurement policies and industrial innovation. Delft: Netherlands Organization for Applied Scientific Research, 1978. [NTIS: PB-100836]

Parrott, Bruce. Information transfer in Soviet science and engineering: A study of documentary channels. Santa Monica, CA: Rand, 1981.

Pavitt, K. and W. Walker, "Government policies towards industrial innovation," Research Policy, 5, 1976, pp. 11-97.

Pennock, J. Roland and John W. Chapman, eds. Compromise in ethics, law, and politics. New York: New York University Press, 1979.

Perry, Robert. American styles of military R&D. Santa Monica, CA: Rand, 1979.

Pfeffer, Jeffrey and Phillip Nowak, "Patterns of joint venture activity: Implications for antitrust policy," The Antitrust Bulletin, 21, Summer 1976, pp. 315-339.

Phillips, Don I., ed. Research in the age of the steady-state university. AAAS selected symposium 60. Boulder, CO: Westview Press, 1982.

Phillips, Don I., Patricia S. Curlin, and Ralph L. Petrilli. R&D in the federal budget: R&D, industry, and the economy, Colloquium proceedings June 20-21, 1978. Washington, DC: American Association for the Advancement of Science, 1978.

Piekarz, Rolf, Eleanor Thomas and Donna Jennings. International comparisons of research and development expenditures. Paper prepared for the American Enterprise Institute Conference "International Comparisons of Productivity and Causes of the Slowdown," September 30 and October 1, 1982. Revised January 1983.

Prager, Denis and Gilbert S. Omenn, "Research, innovation, and university-industry linkages," Science, 207, January 1980, pp. 379-384.

Price, Don K. Government and science: Their dynamic relation in American democracy. New York: Oxford University Press, 1962.

Price, Don K. The scientific estate. Cambridge, MA: Harvard University Press, 1965.

Ramo, Simon. America's technology slip. New York: John Wiley, 1980.

- Ramsey, Douglas, et al., "Japan's high-tech challenge," Newsweek, August 9, 1982, pp. 48-60.
- Reed, Philip G., "Organizational conflicts of interest: The government procurement regulatory problem." Paper prepared in connection with the American Bar Association National Institutes, April 21-22, 1977.
- Research & Planning, Inc. The role of patents in the commercialization of new technology for small innovative companies. Cambridge, MA: undated.
- Rettig, Richard A. and Alvin J. Harman. The development of medical technology: A policy perspective. Santa Monica, CA: Rand, 1979.
- Rettig, Richard A. The use of consortia for the management of research and development. The Clemson University ETIP flammability project. Santa Monica, CA: Rand, 1976.
- Robbins, Martin D. and J. Gordon Milliken, "Government policies for technological innovation: Criteria for an experimental approach," Research Policy, 6, 1977, pp. 214-240.
- Robbins, Martin D. and J. Gordon Milliken, "Technology transfer and the process of technological innovation: New concepts, new models," R&D Management, 6, 1976, pp. 165-170.
- Roberts, Edward B., "New ventures for corporate growth," Harvard Business Review, 58:4, July/August 1980, pp. 134-142.
- Robinson, Clarence A., "Integrated military guidance sought," Aviation Week & Space Technology, May 17, 1982, pp. 174-178.
- Robinson, Richard D., "Can the Japanese keep it up?" Technology Review, August/September 1982, pp. 47-52.
- Roland, Alex. A guide to research in NASA history. 6th ed. Washington, DC: National Aeronautics and Space Administration, History Office, 1982.
- Rosegger, Gerhard. The economics of production and innovation: An industrial perspective. New York: Pergamon Press, 1980.
- Rosenberg, Nathan and David C. Mowery. The development and organization of industrial research and development. Final report. Stanford, CA: Stanford University, Dept. of Economics, 1981. [NTIS: PB83-131961]
- Ross, David A., "How the Law of the Sea Treaty will affect U.S. marine science," Science, 217, September 10, 1982, pp. 1003-1008.
- Rothwell, Roy, "The characteristics of successful innovators and technically progressive firms (with some comments on innovative research)," R&D Management, 7:3, June 1977, pp. 191-206.
- Rothwell, Roy, and Walter Zegveld. Industrial innovation and public policy: Preparing for the 1980's and 1990's. London: Frances Pinter, Publishers, 1981.

- Ruttan, Vernon W., "Changing role of public and private sectors in agricultural research," Science, 216, April 2, 1982, pp. 23-29.
- Sahal, Devendra. The transfer and utilization of technical knowledge. Lexington, MA: Lexington Books, 1982.
- Schlie, Theodore W. The Japanese technological challenge. Paper prepared for the U.S. Dept. of Commerce Professional Communicators Workshop, May 21, 1982.
- Schlie, Theodore W. The theoretical basis for governmental support of R&D: Traditional arguments and new realities. Washington, DC: U.S. Dept. of Commerce, 1981. Paper prepared for the Second U.S.-Japan Science Policy Seminar, Comparative Studies of Policies and Practices for Basic and Applied Science in Japan and the United States, August 24-26, 1981, Honolulu, Hawaii.
- Sciberras, E., N. Swords-Isherwood and P. Senker. Competition, technical change and manpower in electronic capital equipment: A study of the UK minicomputer industry. Brighton, [U.K.]: University of Sussex, September 1978.
- Shosteck, Herschel. An evaluation of the factors influencing successful diffusion and application of scientific technology under the State Technical Services Act: A preliminary study. Washington, DC: U.S. National Bureau of Standards, January 1977. [NTIS: PB-262763]
- Shultz, Eugene B. and William P. Darby. Evaluation of the second Five Year Outlook on Science and Technology. St. Louis, MO: Washington University, Center for Development Technology, April 1982. [NTIS: PB82-197252]
- Smith, Jeffrey R., "A legacy of technical problems," Science, 216, April 30, 1982, pp. 494.
- Southwest Innovation Group. Southwest Innovation Group: Final technical report. Pasadena, CA: October 1979. [NTIS: PB82-147802]
- SRI International. Assessment of U.S. government export financing of high-technology products. Phase I Research report. Menlo Park, CA: September 1981.
- Stephanou, S.E. Management: Technology, innovation and engineering. (A systems approach). Malibu, CA: Daniel Spencer Publishers, 1981.
- Suzuki, N. Country paper on the development scheme for Japanese small and medium scale industries. Vienna: United Nations Industrial Development Organization, 1981. [UNIDO:ID/WG.350/13]
- Taylor, Gail W., "Antitrust law: Joint research efforts in pollution control validated," Wayne Law Review, 20, September 1974, pp. 1321-1326.
- Teich, Albert H., ed. Science, technology, and the issues of the eighties: Policy outlook. Boulder, CO: Westview Press, 1982.

Terleckyj, Nestor E., "What do R&D numbers tell us about technological change?" American Economic Review, May 1980, pp. 55-61.

Tornatzky, Louis G., et al. University-industry cooperative research centers: A practice manual. Washington, DC: National Science Foundation, 1982.

Tybout, Richard A. Economics of research and development. Columbus, OH: Ohio State University Press, 1965.

United Nations Industrial Development Organization (UNIDO). Guidelines for evaluation of transfer of technology agreements. New York: United Nations, 1979. [UNIDO/ID/233]

United Nations Industrial Development Organization (UNIDO). Organization, functions and activities of national technology transfer regulatory agencies. Vienna: 1981. [UNIDO/IS.236]

U.S. Administrative Conference of the United States, "Recommendations of the Administrative Council," Federal Register, 47:130, July 15, 1982, pp. 30701-30714.

"U.S. antitrust policy and joint research," Research Management, 24:1, January 1981, p. 3.

U.S. Congress, House, Committee on Energy and Commerce. Capital formation and industrial policy. Committee print. Washington, DC: Government Printing Office, July 1981. [Committee Print 97-P]

U.S. Congress, House, Committee on Energy and Commerce. Capital formation and industrial policy. (Part 1). Washington, DC: Government Printing Office, 1981. Hearings before the Committee April 27, 29, June 1, 22 and 24, 1981. [Serial No. 97-13]

U.S. Congress, House, Committee on International Relations, Subcommittee on International Security and Scientific Affairs. International transfer of technology. Washington, DC: Government Printing Office, 1979.

U.S. Congress, House, Committee on Interstate and Foreign Commerce; House, Committee on Science and Technology; and House, Committee on Banking, Finance and Urban Affairs. Technology trade. Washington, DC: Government Printing Office, June 1980. Hearings before the Committees, June 24-26, 1980.

U.S. Congress, House, Committee on Science and Technology. Industrial innovation. Washington, DC: Government Printing Office, 1980. Hearing before the Committee July 21, 1980. [No. 159]

U.S. Congress, House, Committee on Science and Technology. Seminar on research and the national economy. Washington, DC: Government Printing Office, 1980. Seminar before the Committee June 18, 1980.

U.S. Congress, House, Committee on Science and Technology, Subcommittee on Domestic and International Scientific Planning and Analysis. Background materials on government patent policies. Washington, DC: Government Printing Office, 1976.

- U.S. Congress, House, Committee on Science and Technology, Subcommittee on Domestic and International Scientific Planning and Analysis. Federal research and development expenditures and the national economy. Washington, DC: Government Printing Office, 1976. Hearings before the Subcommittee on April 29; May 4, 5, 1976.
- U.S. Congress, House, Committee on Science and Technology, Subcommittee on Domestic and International Scientific Planning and Analysis. Government patent policy. Washington, DC: Government Printing Office, 1976. Hearings before the Subcommittee September 23, 27, 28, 29; October 1, 1976.
- U.S. Congress, House, Committee on Science and Technology, Subcommittee on Energy Development and Applications. National laboratory relationships with industry and the university community. Washington, DC: Government Printing Office, 1981. Hearing before the Subcommittee July 29, 1981.
- U.S. Congress, House, Committee on Science and Technology, Subcommittee on Science, Research and Technology. Analyses of President Carter's initiatives in industrial innovation and economics revitalization. Washington, DC: Government Printing Office, 1980. Report prepared by the Subcommittee.
- U.S. Congress, House, Committee on Science and Technology, Subcommittee on Science, Research and Technology. Domestic technology transfer: Issues and options. Washington, DC: Government Printing Office, 1978.
- U.S. Congress, House, Committee on Science and Technology, Subcommittee on Science, Research and Technology. Implementation of P.L. 96-480, Stevenson-Wydler Technology Innovation Act of 1980. Washington, DC: Government Printing Office, 1981. Hearing before the Subcommittee July 14, 15, 16, 1981. [No. 81]
- U.S. Congress, House, Committee on Science and Technology, Subcommittee on Science, Research and Technology. Summary of House and Senate Hearings on Government-University-Industry Relations. Washington, DC: Government Printing Office, 1980. Report prepared by the Subcommittee.
- U.S. Congress, Joint Economic Committee. Productivity. Washington, DC: Government Printing Office, 1979. Hearing before the Committee June 5, 1979.
- U.S. Congress, Joint Economic Committee. U.S. export competitiveness. Washington, DC: Government Printing Office, 1981. Hearing before the Joint Committee July 29, 1981.
- U.S. Congress, Office of Technology Assessment. Applications of R&D in the civil sector. Washington, DC: Government Printing Office, 1978.
- U.S. Congress, Office of Technology Assessment. Civilian space policy and applications. Washington, DC: Government Printing Office, June 1982.
- U.S. Congress, Office of Technology Assessment. Government involvement in the innovation process. Washington, DC: Government Printing Office, 1978.

- U.S. Congress, Office of Technology Assessment. Patent-term extension and the pharmaceutical industry. Washington, DC: Government Printing Office, 1981.
- U.S. Congress, Senate, Committee on Aeronautical and Space Sciences. National Aeronautics and Space Act of 1985, as amended; and related legislation. Washington, DC: Government Printing Office, 1975.
- U.S. Congress, Senate, Committee on Commerce, Science, and Transportation. National strategy for technological innovation. Washington, DC: Government Printing Office, 1979.
- U.S. Congress, Senate, Committee on Commerce, Science, and Transportation; and Committee on the Judiciary. Patent policy. Washington, DC: Government Printing Office, 1980.
- U.S. Congress, Senate, Committee on Commerce, Science and Transportation; and House, Committee on Science and Technology. Federal patent policy. Washington, DC: Government Printing Office, 1981. Joint hearing before both Committees September 30, 1981.
- U.S. Congress, Senate, Committee on Commerce, Science, and Transportation, Subcommittee on Science, Technology, and Space. Federal patent policy. Washington, DC: Government Printing Office, 1981. Hearing before the Subcommittee July 28, 1981.
- U.S. Congress, Senate, Committee on Commerce, Science and Transportation, Subcommittee on Science, Technology and Space. National Technology Innovation Act. Washington, DC: Government Printing Office, November 1979. Hearings before the Subcommittee June 21, 27 and November 21, 1979.
- U.S. Congress, Senate, Committee on Commerce, Science and Transportation, Subcommittee on Science, Technology and Space. Oversight of science and technology policy. Washington, DC: Government Printing Office, 1978. Hearings before the Subcommittee February 10 and April 26, 1978. [Serial No. 95-77]
- U.S. Congress, Senate, Committee on Commerce, Science and Transportation, Subcommittee on Science, Technology and Space. Patent policy. Washington, DC: Government Printing Office, 1979. Hearings before the Subcommittee July 23 and 27, and October 26, 1979.
- U.S. Congress, Senate, Committee on Labor and Human Resources, Subcommittee on Employment and Productivity. Productivity in the American economy, 1982. Washington, DC: Government Printing Office, 1982. Hearings before the Subcommittee March 19 and 26; April 2 and 16, 1982.
- U.S. Congress, Senate, Committee on Labor and Human Resources, Subcommittee on Employment and Productivity. Productivity and the American economy: Report and findings. Washington, DC: Government Printing Office, 1982.
- U.S. 95th Congress. Public Law 95-224: Federal Grant and Cooperative Agreement Act of 1977, February 3, 1978.

- U.S. Dept. of Commerce. Advisory committee on industrial innovation. Final report. Washington, DC: Government Printing Office, September 1979.
- U.S. Dept. of Commerce, "Cooperative generic technology program procedures," Federal Register, 45:159, August 14, 1980, pp. 54028-54031.
- U.S. Dept. of Commerce, National Bureau of Standards. Science and technology: The challenges of the future. Washington, DC: 1982.
- U.S. Dept. of Commerce, Patent and Trademark Office. General information concerning patents. Washington, DC: Government Printing Office, 1976.
- U.S. Dept. of Commerce, Patent and Trademark Office. Technology assessment and forecast: Tenth report. Washington, DC: November 1981.
- U.S. Dept. of Health and Human Services, Project Share. Technology transfer and the management of human services. Rockville, MD: August 1981. [NTIS: PB82-105644]
- U.S. Dept. of Justice, Antitrust Division. Antitrust guide concerning research joint ventures. Washington, DC: Government Printing Office, November 1980.
- U.S. Dept. of Justice, Antitrust Division, "Antitrust guide for joint research programs," Research Management, 24:2, March 1981, pp. 30-37.
- U.S. Dept. of the Interior, Bureau of Mines. Technology exchange seminar: Mining information systems. Washington, DC: April 1982. [NTIS: PB82-251943]
- U.S. Federal Trade Commission, Bureau of Competition. The competitive implications of government-assisted commercialization programs. Conference summary. Washington, DC: 1980.
- U.S. General Accounting Office. Industrial policy: Case studies in the Japanese experience. Washington, DC: 1982. [GAO/ID-83-11]
- U.S. General Accounting Office. Industrial policy: Japan's flexible approach. Washington, DC: June 1980. [GAO/ID-82-32]
- U.S. General Accounting Office. NASA must reconsider operations pricing policy to compensate for cost growth on the space transportation system. Washington, DC: February 23, 1982. [MASAD-82-15]
- U.S. General Accounting Office. Observations on collection and dissemination of scientific, technical and engineering information. Washington, DC: March 19, 1976. [GGD-76-66]
- U.S. General Accounting Office. Patent and trademark amendments of 1980 set the stage for uniform patent practice by federal agencies. Washington, DC: 1982. [GAO/PAD-82-32]

- U.S. General Accounting Office. Regulatory effects on R&D are better assessed as part of the innovation process. Washington, DC: 1982. [GAO/PAD-82-1]
- U.S. Office of Management and Budget, "Circular No. A-124, Patents--Small firms and non-profit organizations," Federal Register, 47:34, February 19, 1982, pp. 7556-7566.
- U.S. Office of Management and Budget. Managing federal assistance in the 1980's. 4 vols. Washington, DC: Government Printing Office, 1980.
- U.S. Regulatory Council. An inventory of innovative techniques, 1978-1980. Washington, DC: 1981.
- "USAF office aids industrial modernization," Aviation Week and Space Technology, May 10, 1982, pp. 60-61.
- Upper Plains States Innovation Group. Upper Plains Innovation Group. Final report. Bismarck, ND: July 1981. [NTIS: PB82-145814]
- Vogel, Ezra F., "Can the Japanese keep it up?" The Innisbrook Papers, date ?, pp. 30-32.
- Waldrop, M. Mitchell, "NASA struggles with space shuttle pricing," Science, 216, April 16, 1982, pp. 278-279.
- Waldrop, M. Mitchell, "NASA wants a space station," Science, 217, September 1982, pp. 1018-1021.
- Weisskoff, Richard, "Linkages and leakages: Industrial tracking in an enclave economy," Economic Development and Cultural Change, 25:4, 1977, pp. 607-628.
- "What the U.S. can learn from its rivals," Business Week, June 30, 1980, pp. 138-142.
- Wilford, John Noble, "Military's future in space: A matter of war or peace," New York Times, October 19, 1982.
- Wissema, J.G., "Trends in technology forecasting." R&D Management, 12:1, January 1982, pp. 27-36.